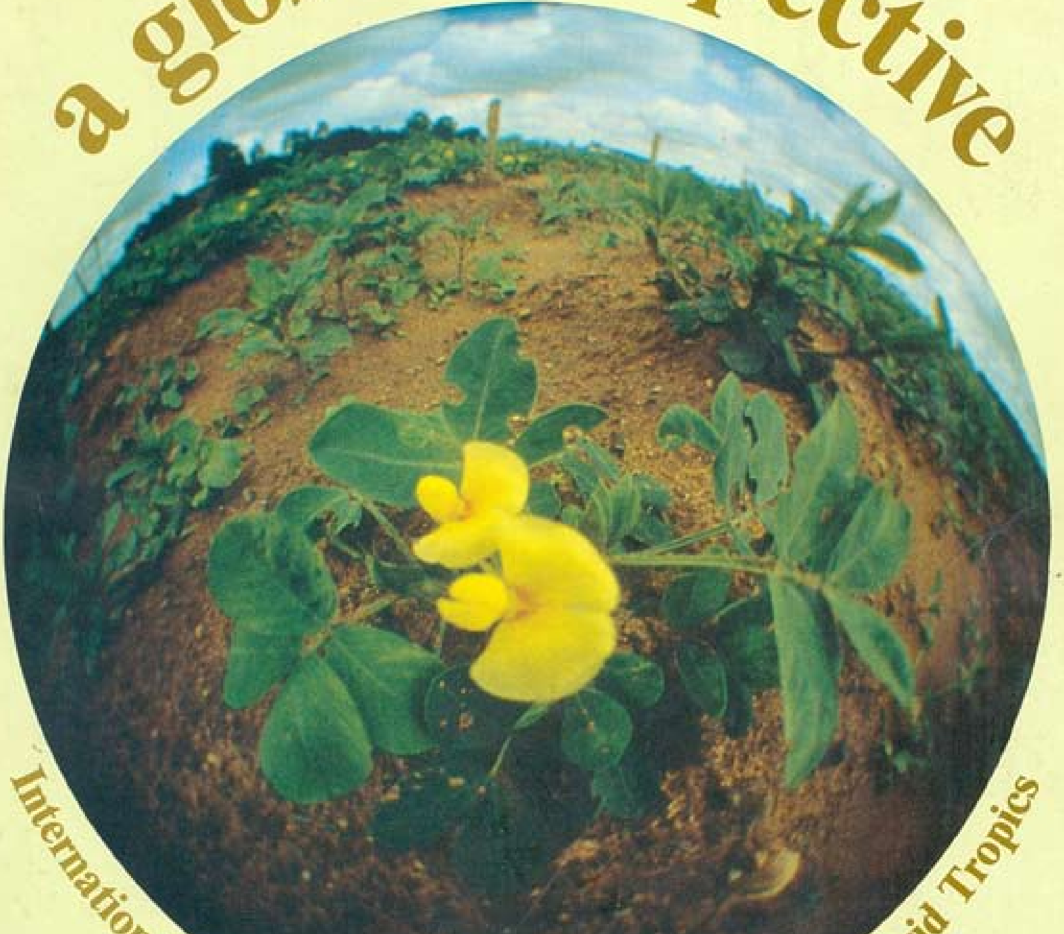
Groundnut a global perspective



International Crops Research Institute for the Semi-Arid Tropics

Abstract

Citation: Nigam, S.N. (ed.) 1992. Groundnut – a global perspective: proceedings of an international workshop, 25–29 Nov 1991, ICRISAT Center, India. (In En. Abstracts in En. Fr. Es.) Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics. 548 pp. ISBN 92-9066-239-5, Order Code: CPE 081.

This workshop brought together scientists working on all different aspects of groundnut research from all parts of the globe. Major papers are presented on: production and trade; regional reviews; donor reports; and special topics including information transfer, processing and products, integrated pest management, genetic resources – including wild species, biotechnology, and crop modeling. Nearly 100 poster abstracts are included. These cover general topics; genetic resources; biotechnology; breeding; crop physiology and nutrition; diseases and insect pests; intercropping and weed management; and processing and products. The proceedings provide a comprehensive record of progress made in groundnut research and production technology in the 1980s. The workshop recommendations, originating from disciplinary group discussions, outline the future research requirements of the crop.

Résumé

L'arachide—une perspective mondiale: comptes rendus d'un atelier international, 25–29 novembre 1991, Centre ICRISAT, Inde. Cet atelier a réuni des chercheurs provenant de toutes les régions du monde qui travaillent sur les divers aspects de la recherche sur l'arachide. Des communications importantes sont présentées sur: la production et le commerce; les revues régionales; les rapports des donateurs; ainsi que des sujets particuliers comprenant le transfert d'informations, la transformation et les produits, la lutte intégrée contre les ravageurs, les ressources génétiques, y compris les espèces sauvages, les biotechnologies et la modélisation des cultures. Près de 100 résumés des affiches scientifiques sont inclus. Ceux-ci couvrent les sujets généraux; les ressources génétiques; les biotechnologies; la sélection; la physiologie et la nutrition des cultures; les maladies et les insectes ravageurs; la culture associée et la gestion des mauvaises herbes; et la transformation et les produits. Les comptes rendus offrent une présentation détaillée des progrès effectués en matière de la recherche et la technologie de production de l'arachide pendant les années 1980. Les recommandations de l'atelier, provenant des discussions de groupes par discipline, esquissent les besoins futurs en matière de recherche sur cette culture.

Resumen

El maní—una perspectiva global: actas de un taller internacional, 25–29 noviembre 1991, Centro ICRISAT, India. Este taller reunió científicos procedientes de todas partes del mundo trabajando en distintos aspectos de investigación sobre maní. Se incluyen conferencias sobre producción y comercio; repasos regionales; informes de donores; y temas específicos como transferencia de technología, procesamiento y productos, manejo integrado de plagas, recursos genéticos incluyendo especies silvestres, biotecnología y modelado de cultivos. Se incluyen casi cien resúmenes abarcando temas generales; recursos genéticos; biotecnología; cruzamiento; fisiología y alimentación; enfermedades e insectos nocivos; manejo de hierbajo; procesamiento y productos. Las actas proveen un informe amplio del progreso alcanzado en investigación sobre maní y las tecnologías de producción en los años 80. Las recomendaciones del taller que surgieron en discusiones y debates en grupo, marcan las pautas a seguir en futuras investigaciones sobre maní.

Groundnut – A Global Perspective

Proceedings of an International Workshop

25–29 Nov 1991
ICRISAT Center

Edited by

S.N. Nigam

ICRISAT

International Crops Research Institute for the Semi-Arid Tropics
Patancheru, Andhra Pradesh 502 324, India

1992

Co-sponsors

International Crops Research Institute for the Semi-Arid Tropics

Peanut Collaborative Research Support Program

Centre de coopération internationale en recherche agronomique pour le développement

The International Crops Research Institute for the Semi-Arid Tropics is a nonprofit, scientific, research and training institute receiving support from donors through the Consultative Group on International Agricultural Research. Donors to ICRISAT include governments and agencies of Australia, Belgium, Canada, China, Finland, France, Germany, India, Italy, Japan, Korea, Mexico, Netherlands, Nigeria, Norway, Sweden, Switzerland, United Kingdom, United States of America, and the following international and private organizations: African Development Bank, Agricultural University of Wageningen, Asian Development Bank, Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ), International Board for Plant Genetic Resources, International Development Research Centre, International Fertilizer Development Center, International Fund for Agricultural Development, International Fund for Agricultural Research, The European Economic Community, The Opec Fund for International Development, The Rockefeller Foundation, The World Bank, United Nations Development Programme, University of Arkansas, University of Georgia, University of Hamburg, and University of Hohenheim. Information and conclusions in this publication do not necessarily reflect the position of the aforementioned governments, agencies, and international and private organizations.

The opinions in this publication are those of the authors and not necessarily those of ICRISAT. The designations employed and the presentation of the material in this publication do not imply the expression of any opinion whatsoever on the part of ICRISAT concerning the legal status of any country, territory, city, or area, or of its authorities, or concerning the delimitation of its frontiers or boundaries. Where trade names are used this does not constitute endorsement of or discrimination against any product by the Institute.

ISBN 92-9066-239-5

Contents

Inaugural Session

Introductory Remarks

D.McDonald[1]

On behalf of ICRISAT's management and our scientists at all locations involved in groundnut research and associated information and training activities, I welcome our distinguished guests and participants in this meeting.

Our first International Workshop on Groundnuts was held in this auditorium in October 1980, almost exactly 11 years ago. It was attended by 71 groundnut scientists representing 20 different countries. Today we have 165 participants from 44 countries. We could not have achieved such a wide representation had it not been for the financial support provided by the U.S. Peanut Collaborative Research Support Program (Peanut CRSP), the French Ministry of Cooperation through the Centre de coopération internationale en recherche agronomique pour le développement (CIRAD), France, and the Canadian International Development Research Centre (IDRC). These organizations sponsored the participation of many delegates from developing countries.

It is not only external participation that has increased. Over the past 11 years there has been a very considerable increase in interdisciplinary research within ICRISAT and many independent lines of research have come together with greater emphasis being given to integration of improved varieties with more effective crop management systems. The increased role of our Resource Management Program scientists in addressing groundnut production problems is particularly evident, and they will have a leading part to play in the satellite workshop on groundnut modeling on Thursday and Friday. The involvement of information and training programs has also increased. But perhaps the most notable development has been the much-increased interaction of our scientists with those of national agricultural research systems through the establishment of regional ICRISAT Centers in West and southern Africa, and the creation of the Asian Grain Legumes Network.

The focus of this workshop is very much on international approaches towards improvement of production and quality of groundnuts. We hope to discuss constraints to production in the various groundnut-producing regions of the world, and to come up with some guidelines for international research and development work on the crop for the next 10 years. Reports from donors, special research topics, and concurrent discussion sessions are included in the program. Field and laboratory visits are also included. As the workshop has focused mainly on reviews and general reports on research progress, there are not many papers on specific research projects. However, to provide an opportunity for individual scientists to report on their work we have arranged for an extensive demonstration of poster papers. I hope you will all try to visit the posters and discuss the work with the scientists concerned.

The Organizing Committee has done a very good job in preparing the program and, together with Food and Housing and other supporting units, has tried to cover most eventualities. Information on these arrangements is included in the Program and in other papers given to you in the Workshop bags. However, if any of you do have problems, please contact any member of the Legumes Program staff who will be pleased to assist.

Finally, I am particularly pleased to note that we are welcoming back to ICRISAT 12 "survivors" of the 1980 Workshop. You all appear to have weathered most successfully the stresses occasioned by 11 more years of groundnut research, and to provide concrete evidence of this I have had an enlarged photograph of the participants at the 1980 Workshop put on display. We hope to obtain a photograph of the participants at the present meeting on Thursday morning, and perhaps some of you may be looking at it when you attend the Third Workshop next Century!

Thank you all very much for coming to ICRISAT and I trust that you will have a successful and enjoyable week.

1. Program Director (Legumes), International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, A.P. 502 324, India.

Keynote Address

J.G. Ryan[1]

As many of you know I have had only 3 months 'in seat', but I am here for the second time, so the environment is not new to me. As you can imagine, I do have to catch up on a few things. I anticipate that this workshop will enable me to refresh my memory of groundnut science and technology.

An important milestone which passed during my first period at ICRISAT was the acceptance by the Governing Board and by the CGIAR of a proposal for the formation of a Groundnut Improvement Program. As I was part of the committee that formulated this proposal, it is not surprising that I have a personal interest in examining if, how, and why the existing structure and modus operandi of what is now the Groundnut Group of the Legumes Program differs from the pattern envisaged by Bunting, Gregory, Mauboussin, and myself some 17 years ago.

Also, on looking through the program of the workshop, I could not help but notice that there is something of an omission in that there is no specific slot for ICRISAT to describe its place in the groundnut world.

Firstly, I shall outline for the benefit of delegates who are new to this Institute, ICRISAT's mandated function. I shall show how it fulfills part of that function by using the Groundnut Group as an example. This will, in turn, enable me to illustrate the scope of the groundnut-related work of the Institute.

So I thought that this introduction would give me the opportunity to do several things at one time.

We have completed our strategic plan and are now converting it into an operational plan. This means that I can give some idea of future directions. However, this organization has to be somewhat 'demand driven' by our partners, although I have to point out that we cannot answer these demands without taking heed of the 'supply' sector - the Consultative Group on International Agricultural Research (CGIAR), the donors, and its Technical Advisory Committee (TAC). But, as no policy is ever cast in concrete, I shall be interested to read the final recommendations of the workshop and will discuss with my colleagues how we can accommodate portions that are relevant to our mandate.

I should like to run through the concepts that supported the initiation of a Groundnut Group at ICRISAT in 1974 and compare the challenge defined by Bunting et al. at that time with the scientific progress and impact since then.

I should also like to indicate how the Groundnut Group functions, both within the Institute and with other organizations.

Having looked back, and then reviewed the present situation, I shall look to the future and make some predictions about what is going to happen in the world of groundnuts by the year 2001.

ICRISAT's mandate is to:

- Serve as a world center for the improvement of grain yield and quality of sorghum, millets, chickpea, pigeonpea, and groundnut and to act as a world repository for the genetic resources of these crops;
- Develop improved farming systems that will help to increase and stabilize agricultural production through more effective use of natural and human resources;
- Identify constraints to agricultural development in the semi-arid tropics, and evaluate means of alleviating them through technological and institutional changes; and
- Assist in the development and transfer of technology to the farmer through cooperation with national and regional programs, and by sponsoring workshops and conferences, operating training programs, and assisting extension services.

Within this formal mandate it is possible to add a number of guiding values.

- Equity – a dedication to helping the poorest of the poor in the semi-arid tropics and in the other ecological zones in which our crops are grown. Help can be offered in terms of providing ways of increasing the

1. Director General, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, A.P. 502 324, India.

efficiency of their food supply and in improving their economic well-being. Groundnut is important in both regards – it is an important food – and it can be sold – to provide farm inputs, and to pay for childrens' education, for instance.

- The Institute was ahead of many others in realizing that there was, and still is, a desperate need to help farmers in sub-Saharan Africa. There are therefore two groundnut teams in Africa. The one in Malawi covers the problems of the Southern African Development Coordination Conference (SADCC) countries, and the one at ICRISAT's Sahelian Center in Niger works with our French colleagues towards solving specific problems of groundnut production in West Africa.
- The ICRISAT Center-based Groundnut Group has responsibility for solving Asian problems. This function has been facilitated by the creation of the Asian Grain Legumes Network (AGLN) in 1984. It also gives support of a more basic nature to African colleagues, especially for disciplines that are not fully represented in Africa: virology, entomology, and nematology, for example.

Interdisciplinary research within the Groundnut Group is the norm. It gives rise to new technology that is tested in farming systems with or by the Resource Management Program. There is an increasing trend for a new technology to be tested by farmers earlier in its development than was previously the case.

Our main partners are the National Agricultural Research Systems (NARS); we often work as intermediaries for the transfer of technology from specialized research organizations in the 'West' to where it may be needed in the less-developed countries.

While mentioning partners, this is an opportune moment to express the Institution's gratitude to the United States Agency for International Development (USAID), the Peanut Collaborative Research Support Program (Peanut CRSP), the Centre de coopération internationale en recherche agronomique pour le développement (CIRAD), and the International Development Research Centre (IDRC) for providing support to many of the delegates we are pleased to welcome today.

I should also like to express thanks to all the other agencies who support the work of the Groundnut Group in terms of financial backing and scientific partnership. It is most pleasing to know that many are represented at this workshop.

Research Priorities and Strategies

A characteristic of this and other Consultative Group Centers is the continuous reappraisal of research direction and priorities. This is particularly necessary in our current phase of constrained funding. There are six processes relevant to the prioritization of research within the Groundnut Group.

Process 1 – Regional groundnut scientists meetings

The AGLN-sponsored meeting of groundnut scientists in November 1989 in Malang, Indonesia permitted Asian specialists to interact with representatives of the Peanut CRSP, the Australian Centre for International Agricultural Research (ACIAR), IDRC, Winrock, and ICRISAT. The meeting recommended emphasis on insect pest surveys, shade tolerance, and acid soil tolerance.

A follow-up meeting was held in Los Baños in April 1990, and was hosted by the Philippine Council for Agriculture, Forestry and Natural Resources Research and Development (PCARRD) and the Peanut CRSP, to discuss how work could start on these topics.

The two African programs also organize formal regional workshops. These give ICRISAT's partners a regular opportunity to indicate regional priorities.

Process 2 – Asian Grain Legume On-farm Research Project (AGLOR)

The United Nations Development Programme has financed a 3-year project in which the Groundnut Group and associated scientists are working with the research and extension staff of NARS in farmers' fields in Sri Lanka, Nepal, Indonesia, and Vietnam. They have analyzed farmers' current practices and are evaluating potential improvements to the traditional methods. This approach, which involves strong interactions with farmers, gives clear guidance on where the scientists need to concentrate their problem solving activities.

Process 3 – Priority setting

The third process reflects my own interest in the broader aspects of priority setting. Groundnut scientists have constructed matrices of perceived groundnut production constraints on the basis of countries or parts of countries. They have rated each constraint for intensity, potential mode of relief, and research status. This process has been partially completed for Asia. The result is available for inspection in the technology transfer display.

Asian delegates are requested to examine the display and tell us whether you agree with my colleagues' assessment. Delegates from other countries are requested to help us extend this process to Africa and the Americas. There are specially designed forms in your bags to help you do this.

You can help us even more by indicating on these forms, firstly, the average percentage loss that can be attributed to each constraint over a 10-year period and, secondly we should like you to indicate whether we should be considering subdivisions of your countries as separate groundnut growing regions. If this is the case it would help greatly if you could indicate the nature of these subdivisions.

This is the first step. The priorities across countries and by agroclimatic zone will then be examined. One reason for doing this is to detect spillover potential. This refers to those areas between which it should be possible – on account of the similarities in constraints, climate, and soil – to transfer or exchange technology with the greatest possibility of success and hence have the greatest socioeconomic impact.

Process 4 – In-house reviews

Each program holds an in-house review every 2 or 3 years in which progress in all projects is assessed from the viewpoint of value of the research.

Process 5 – Meetings

It is part of our mandated duty to host large and small meetings to discuss and prioritize areas of impact either across the mandate crops as a whole as in this meeting or within discrete topics, such as the management of a disease.

Process 6 – Program assessment

The final process involves balancing the multiple impressions of the strengths and weaknesses of a given country's research and extension programs, with the importance given to groundnut by the national policy makers. There is little point in expending our resources on a country unless we know that there will be a reciprocal response in the form of the appropriate strengthening of NARS and the extension services to apply relevant technology. It is also important for us to find out how much technology developed during interactions with teams from the Peanut CRSP, the Canadian International Development Agency (CIDA), and ACIAR, for instance, has been adopted by researchers and, of course, by farmers.

International Position

One of ICRISAT's comparative advantages is that we are apolitical. We can work with combinations of countries on a multilateral basis that would not be permitted to some governmental agricultural support organizations.

For instance, we are extremely pleased that the French teams are so strong in West Africa and that the Peanut CRSP has made a concentrated effort to support NARS in Burkino Faso, Thailand, the Philippines, and the Caribbean. ACIAR has supported the Indonesian program and the Canadians have made considerable impact in South Asia. This reduces ICRISAT's direct responsibility in these countries to learning from these projects and to giving complementary support if or when requested (often in the form of germplasm). At the same time, we know that it is possible to concentrate our limited resources elsewhere, confident that large and important NARS programs are not being neglected. Clearly this is a factor in our decision-making process.

On the subject of our apolitical status, it will be interesting to see if South Africa, Cambodia, North and South Korea, Laos, and Taiwan are represented at our next meeting.

Original Groundnut Research Objectives for ICRISAT

The original objectives proposed by Bunting, Gregory, Mauboussin, and Ryan were given under six headings:

- Protoplasm,
- Protection,
- Production,
- Postharvest technology and use,
- Prices, profits, and people, and
- Professional training and outreach.

As a basic premise it was suggested that in setting up the program it was necessary to link "elements common with other commodities in such a way that the relevant disciplines are not fragmented". This has been done and was reinforced by the suggestion of the 1984 External Management Review to link the two cereal and three legume commodities into discrete programs under the leadership of Directors with executive status. This is one of the Institute's strengths.

There is still more potential for amalgamation, especially where there is a need to concentrate on thematic areas. However, we should probably proceed with the development of informal multidisciplinary groupings before considering the modification of an administrative structure that works pretty well.

Germplasm and cell biology

The Bunting, Gregory, Mauboussin, and Ryan proposal called for the world collection of groundnut germplasm to be housed at ICRISAT and that it should be drawn from the national collections of India, USA, etc. This has been done as a result of international cooperation. Additions to the collection have been made by regular collection expeditions, which are by no means over. For instance, we should like to extend work with our Latin American colleagues to obtain more material from South America, especially of the wild species.

No duplicate collection has been set up, despite the recommendation. Perhaps we should look towards setting up duplicate collections in West and southern Africa? I am also aware that the data bank of our Genetic Resources Unit could be made more accessible to non-ICRISAT personnel.

We noted in the original proposal that the International Board for Plant Genetic Resources (IBPGR) was also formed in 1974. It was later agreed that ICRISAT should have responsibility for the groundnut germplasm, an arrangement that has worked very well for all concerned. Groundnut accessions now number 13 841, of which 7% await registration. Wild species were recognized as a source of late leaf spot resistance. Progress has been made in this direction but there is now concentration on gene mapping and exploiting the wild species as sources of resistance to the more refractory biotic constraints – early leaf spot, the groundnut leaf miner, *Spodoptera*, and white grubs.

A cytogenetics laboratory was established early in the history of the group. Its formation probably marked the first departure in the Consultative Group on International Agricultural Research (CGIAR) from traditional methods of crop improvement to what we would now classify as biotechnology. Indeed the cytogeneticists have completed much of the basic work and have now been transformed into cell biologists with a wider interest covering our three mandate legumes. They are now equipped to take advantage of developments in advanced laboratories elsewhere in the world that are applicable to the needs of groundnut and the two pulses. One of their jobs is in fact to encourage other organizations to carry out research on a cooperative basis that is relevant to the needs of ICRISAT crops.

The taxonomy of *Arachis* species as a whole remains a problem, but this is out of ICRISAT's hands at present.

Breeding

The Bunting panel commented on the possibility of selecting lines from existing cultivars and single plants because groundnut is a natural inbreeder. This is, in fact, akin to the process that led to the selection of ICGS 11 and ICGS 44 from Robut 33-1. However, the breeding program has concentrated more on the conventional hybridization procedure and has done well, with eight varieties released in India, and with combinations of nine varieties released in nine other countries. Quite a few more are close to release elsewhere.

Seed production was mentioned. It still remains a major constraint in many developing countries. This workshop may consider formulating a recommendation indicating that this is a potential thrust area for future attention.

Crop protection

Late leaf spot and early leaf spot were noted to be of the widest importance. Suggestions were made to "design a strategy for (disease) resistance breeding". This was done and the complete germplasm collection has been screened for resistance to late leaf spot and rust (which became pandemic in the intervening period). This process revealed more than 200 lines with late leaf spot and/or rust resistance.

The 1974 committee predicted that 'breeder material' (presumably meaning 'populations') should be available in 5 years and production varieties in 10–15 years. In fact, the ICRISAT foliar diseases resistant cultivar ICG(FDRS) 10 was available for release in India just 10 years after the Groundnut Improvement Program was started. It combines high yield with resistance to rust, late leaf spot, bud necrosis disease, groundnut leaf miner, and drought. It is clearly adapted to rain-fed conditions in southern and central India.

Early leaf spot disease remains a refractory problem. Screening in Malawi may recently have revealed resistance in cultivated groundnut. Attention is being focused on the transfer of resistance from other *Arachis* species. Other options for management are being tested with an Integrated Pest Management (IPM) approach in mind.

Diseases caused by root and crown rot fungi were played down in 1974 and, indeed, it is only now, perhaps as inoculum builds up in farmers' fields, that we are having to take more interest in this set of constraints.

Action on the aflatoxin front was called for and has been delivered in terms of increasing our understanding of seed-coat resistance, and the effects of drought, soil type, and management. The problem cannot be considered to be solved, because resistance breeding has been only partially successful and, to a large part, it depends on the quality of the product at harvest and the subsequent storage and transport conditions. The literature on aflatoxin in groundnut published between 1960 and 1990 has been reviewed. Hard copy and CD-ROM versions in the form of an annotated bibliography are now available.

Groundnut viruses seem to have proliferated at a much greater rate than virologists because the major stress in 1974 was only on the groundnut rosette virus. It was suggested that ICRISAT should limit its attention to "keeping in touch" with work in Malawi and Kenya. I shall return to this theme later. This is one area where there has been considerably more activity than was anticipated in 1974.

Insects

In retrospect, the Bunting team seemed to be slightly at a loss here. However, it should be realized that, at that time, few insect pests of groundnut were recognized. Indeed, it is only since the increased availability of irrigation in India and elsewhere has permitted the postrainy season production of groundnut, that insects such as

Spodoptera have become pests. Unfortunately, the practice of insecticide overapplication in Asia has destroyed the natural control processes that once kept population densities of such insects in check. The major thrust of our IPM work in Asia is to find ways of reversing these trends.

Luckily, insecticide application is not a high priority with most of Africa's groundnut farmers. However, soil insects, especially millipedes, termites, and white grubs, are important constraints on that continent. Whilst the effects of termites and millipedes have been well known for some time, white grubs have apparently gone unnoticed. This is quite possible in view of the hard physical work involved in studying them. Alternatively, the relatively recent development of more settled, cereal-based agricultural systems may have favored their proliferation. White grubs are also key pests across Asia.

Nematodes

The pest potential of nematodes was recognized in 1974. Subsequent experience has indicated that they can indeed be major constraints in West African and Chinese cropping systems. Thankfully, they appear to be less of a problem elsewhere in the groundnut growing world.

Weeds

Little was suggested and little has been done on groundnut weeds, although it is generally recognized that an anticipated shortage of family and/or hired labor can make farmers decide against sowing groundnut. This seems to be one area where western technology in the form of suitably formulated, preemergence herbicides might be adopted in less-developed countries, if the cost could be accommodated within the economic framework of the farm as a whole.

Not much attention has been given to the trade-off between yield suppression by weeds and their value within farming systems as forage and fodder. They also have value as the reservoir of the natural enemies of potential insect and disease pests. However, there are many other aspects of the management of groundnut that impinge on this kind of farming systems- sustainability issue. These come to light as we move away from the straightforward discipline-orientated issues that formed the basis of our proposal in 1974.

Quarantine

Problems were anticipated in 1974, but the process works well in most countries, and we particularly value the close working relationship we enjoy with our host country. International agricultural research centers could hardly operate without such cooperation and, in the absence of effective facilities to support the low risk, international exchange of plant material.

Agronomy

The need to be able to optimize production on our own nstation was stressed by Bunting et al. This has been done. It was then and is still necessary to establish the yield potentials of test genotypes under uniform conditions.

Similarly, as was also proposed, there has been little conventional agronomic research within the Groundnut Group, for the reason stated: its tendency to be location specific. The so-called broad-bed and furrow technology can be advantageous on and off the ICRISAT stations, but should not be regarded as a universal panacea for all SAT groundnut farms.

The Legumes On-Farm Testing and Nursery (LEGOFTEN) unit experience proved the panel to be prophetically correct in that the acumen developed at ICRISAT Center spilled over into an extension exercise that has benefited many farmers in India and may help elsewhere in Asia (via AGLOR).

We might still look at the seed dormancy factor a little more closely.

Factorial maximum yield experiments have not been carried out, despite their suggestion on several occasions by scientists.

Physiology

The original plan called for a great deal of physiological back-up for the breeders. This has taken place, with emphasis on detecting and understanding drought tolerance. The discovery of the amount and variability of photosensitivity in groundnut genotypes could not have been anticipated. Progress has also been made in developing an understanding of nutritional factors, especially iron chlorosis. There is still plenty of scope for strategic research on groundnut physiology and modeling and for interdisciplinary research between physiologists and scientists from other disciplines.

Research on groundnut *Rhizobium* is largely completed. High-quality inoculants are available but not always necessary, because of the comparative aggression and effectiveness of strains that already exist in many environments.

Mechanization

This remains an area worthy of considerable input. The need for effective, low-cost harvesters and threshers remains. It is doubtful, though, if publicly funded research institutions, such as ICRISAT, have a comparative advantage over private sector engineering companies.

Postharvest technology

As the original proposal states – "much could be done". However, much has been done outside of ICRISAT. Perhaps part of our job should be to help make available the existing knowledge. Other than the aflatoxin work, our small input has been into the methodology of monitoring resistance to key insect pests of stored groundnut, and to demonstrating that it is possible to control these pests simply and cheaply in stored seed.

Prices, profits, and people

The Panel indicated that the Groundnut Group will need to be continuously aware of current and predicted movements in production, trade, farm gate, and consumer prices of groundnut products. This is true, but it is largely up to interested individuals to access data from the Food and Agriculture Organization of the United Nations (FAO), the International Food Policy Research Institute (IFPRI), and the Regional Coordination Centre for Research and Development of Coarse Grains, Pulses, Roots, and Tuber Crops in the Humid Tropics of Asia and the Pacific (CGPRT), which are readily accessible in the library or in the Economics Group.

Activity by the ICRISAT economists in the late 1970s, and early 1980s gave clear indications of market structures, nutrient demand elasticities, and consumer preferences for groundnut quality. The latter was particularly useful to breeders. All of this work was restricted to India, which is understandable in view of the economic importance of groundnut products in this country. However, I can see a case for a continuing dialogue between economists and groundnut scientists in India and in other countries to update our perceptions of the importance of groundnut to the governments, farmers, processors, and consumers of partner countries.

Training and outreach

Training and outreach is now called human resource development (HRD) and technology exchange. Irrespective of the titles or euphemisms, these activities remain an important function of ICRISAT as a whole. The technology exchange activity has been extended and facilitated since the formation of the AGLN made it easier to work with Asian partners. Since 1984 the Group has devoted much more of its human and financial resources to network and collaborative research activities with Asian NARS than was possible earlier.

HRD has always been a prime function of the two African groundnut programs. Studying the proceedings of the Regional Workshops indicates that progress has been made in terms of impact and technology transfer. For instance, it is possible to detect increased enthusiasm for this crop simply because the national program specialists know that there are international support teams in their regions that are willing to work with them to solve the relevant problems. The African teams have also been successful in sorting out some well-adapted, high-yielding varieties that should have some impact in the not-too-distant future.

How the Groundnut Group Works

I mentioned the groundnut rosette virus earlier on. I should like to use the research effort on this disease to illustrate how the Groundnut Group:

- Can switch from basic to applied research,
- Has developed strength through its interdisciplinary nature, and, most importantly,
- Is able to act as the catalyst that draws together experts from the world community, many of whom are here today.

This particular disease, which is restricted entirely to Africa, has been subjected to a three-pronged attack.

The development of diagnostic and detection methods

This has to a large extent taken place in Scotland, Georgia, and Germany, and is linked with the Nigerian and Malawian National Programs (with input from ICRISAT staff, especially in Malawi). As a result of this work we now know that the disease does not manifest itself unless two viruses are present in the plant. The symptom-causing agent does not become a pathogen unless associated with an assistor virus. Both are aphid transmitted, but their epidemiology outside the groundnut crop is still largely unknown. This remains as a major void in our knowledge of this disease but can now be approached with considerably greater chances of success because of the diagnostic tests that are now available.

Resistance to the virus

This has been the main avenue of research for many years, the intention being to supplement the simple, effective but not always practical recommendation to sow early and close. Resistance to the virus was detected by French scientists working in West Africa many years ago. These sources have provided the rosette resistance genes that form the basis of current projects to improve the adaptation of groundnut to a number of West and southern African environments.

Vector management

ICRISAT's Genetic Resources Unit (GRU) supplied 6000 lines to be screened for resistance to aphids by ICRISAT's entomologists in India. Of these, one had a high degree of resistance. Subsequent tests in Malawi demonstrated that the resistant genotype stood up to challenge by the local aphid biotype. Exposure to a high level of infestation pressure showed that the vector resistance in this genotype protected it from virus infestation under rigorous field conditions. Further tests in India showed that the aphid-resistant line also has resistance to jassids (*Empoasca kerri*), another SAT-wide insect pest.

Subsequently, scientists from the Natural Resources Institute (NRI) in the UK identified the resistance factor (this work is demonstrated on a poster). The chemical detection of the resistance marker is now the basis of a study of the genetics of aphid resistance being carried out by breeders.

In the intervening time, consignments of the aphid-resistant genotype have been sent to China, Indonesia, and Thailand. This was arranged through AGLN. We have heard from China, where aphids are a pest in their own right, that the resistance is maintained in field conditions. We still await data from Indonesia and Thailand.

Thus, a project starting out with the material from the Genetic Resources Unit (GRU) gene bank linked with ICRISAT Center entomologists traveled to Malawi, and came back to ICRISAT Center for a basic study by experts from a sister institute.

ICRISAT and coworkers have made available a germplasm line that combines resistance to a virus and two species of insect pest, factors that are relevant to groundnut farmers (and breeders) across two continents.

The work on the groundnut rosette virus illustrates:

- How basic and strategic research is carried out to solve complex problems, and
- The effectiveness of the international working group concept for solving complex multidisciplinary problems.

There is a similar network in operation with ACIAR and the Peanut CRSP in Asia for the peanut stripe virus, but you will hear more of that later.

Impact

Impact is one of the more difficult topics to address, especially in a forum like this because of the risk of appearing parochial. Therefore, I quote an independent source.

In explaining how the 'oil seeds revolution' happened in India, economist P.V. Shenoi, the head of India's Oilseed Technology Mission, pointed to ICGS 11, ICGS 44, and ICG(FDRS) 4 as having the potential to give yields well ahead of the national average of 0.8 t ha^{-1}. The same author provided evidence to show that the transfer of the technology applied on the ICRISAT stations to farmers' fields via LEGOFTEN (linked with favorable support prices) also contributed to the recent upturn in groundnut production in India.

Looking at bare statistics, the 60 000-plus groundnut germplasm samples sent out from ICRISAT Center have contained genes that have or will contribute to increased sustainability of groundnut production around the world. Thirty or more varieties bred at ICRISAT have been nominated as parents in the Indian National Program. Many varieties are in advanced stages of testing by breeders and agronomists in many parts of the world.

In less tangible terms, mention can be made of the contribution of the Groundnut Group to the programs of the 1000 or more participants in in-house human resource development activities at ICRISAT Center and to the numerous specialist courses on groundnut science that have been held in conjunction with national scientists of partner countries.

The Groundnut Group has built up a significant body of knowledge and has identified many people on whom it can call for specialist support. I suspect that the main impact of the Groundnut Group and its many coworkers will occur over the next 10 years, a period during which the exchange of groundnut technology will feature highly among our activities. The adoption of the role of oracle leads me to my concluding comments.

The Future

I should like to look ahead to what will be the status quo for groundnut in the year 2001. I suspect that over the next 10 years, groundnut productivity will swing upwards, particularly in developing countries. Obviously, I hope that one reason for this will be that the improved technology, which is to be discussed during this workshop, will come on-line. There will be a number of contributing factors both of an economic and of a technological nature:

1. In India, the world's largest consumer of groundnut oil, income and population growth will lead to the continuing increase in demand for this high status product.
2. Urbanization will continue across the developing world and with it will come the demand for packaged and processed food. Groundnuts are eminently suitable for cheap 'fast foods', both in the natural state and after processing. They could eventually displace soybean products on world markets because raw groundnut has flavor and nutritional advantages.

3. The burgeoning middle classes that will develop as city-based trading activity proliferates will increase the demand for snack food, a trend already apparent in Brazil, for instance. Thus, sustained attention to confectionery varieties will lead to an early payoff.
4. Increased production and productivity will become possible as more land, water, and other resources are allocated to groundnut production because of the need to fill the increased demand. This process will be led by sustained increases in the farm-gate price, but it will not occur unless the system of organized markets is extended into the remoter areas of the three continents involved. The high and guaranteed support prices associated with sustained demand will contribute to this trend.

Looking towards the research and technology scene in the year 2001:

I can foresee that we shall be much closer to being able to predict insect, disease, and drought incidence by means of satellite imagery. This will be linked to geographic information system technology that will enable us to mark out, in real time, specific 'disaster watch' areas.

The geographical information system will also help us to match genotype and management practice with environment on a much finer grid than we are attempting at present.

Computer modeling of constraint incidence across environments will also help us decide on the appropriate balance between genetic and/or management solutions.

The concept of developing an insight into the balance between the heavy investment by research institutes into breeding programs versus other approaches to crop and farming system improvement will have been addressed – this is one aspect of the research on research concept. The other is the imperative to assess, articulate, and demonstrate that all of our research ultimately has impacts on the productivity, stability, and sustainability of groundnut production such that the socioeconomic well-being of the poor is enhanced.

The increasing public sensitivity to environmental issues is a worldwide phenomenon and is already making the agrochemical industry nervous about its profits and image. In 10 years time the stocks of insecticides that are illegal in the West but which find their way into the market in LDCs may be exhausted. Unfortunately, the continuing abuse of pesticides will, in any case, have caused wide-scale pesticide resistance among target organisms, and among organisms that are not yet pests.

For these reasons, I can foresee that strategic IPM-orientated research will become an increasingly important component of the research portfolio of publicly funded research institutes such as ICRISAT. By its nature, IPM cannot be packaged. It is not crop or system specific. If impact is to be made, a prerequisite is the formation of farmer-orientated, fully integrated multidisciplinary teams with critical mass.

We can anticipate that some of the rational pest management practices that are already understood will have been adopted by small farmers. The more commercialized, large farmers will be slower to adopt more sustainable but, in the short term, less profitable practices. Progress at ICRISAT in this field will come about as a result of the proposed shift in emphasis to on-farm evaluation – with farmer feedback – of the technology developed on the research station.

IPM and other constraint-alleviating activities will have been strengthened by the provision of varieties that have genes derived from wild species of *Arachis*, especially those in the more refractory section *Rhizomatosae*. Now that high yielding varieties are available, the main thrust will be in breeding varieties that exhibit sustainable production in clearly defined environments. This process will be supported by the fruits of the Cell Biology laboratories of ICRISAT and our many cooperators.

Looking at ICRISAT's role, I predict that the current trend for our Groundnut specialists to be undertaking collaborative research with our NARS partners will continue. This will include NARS scientists carrying out research at the various ICRISAT centers on problems that are specific to the needs of their countries.

I look forward to hearing your views on the future of groundnut.

Acknowledgment

I wish to acknowledge the help I received in preparing this contribution from Drs J.A. Wightman and S.N. Nigam of ICRISAT.

Groundnut Production and Trade

Groundnuts: Production, Utilization, and Trade in the 1980s

S.M. Fletcher, Ping Zhang, and D.H. Carley[1]

Abstract

*Groundnut (*Arachis hypogaea*) is one of the principal oilseeds in the world. Even though groundnut has experienced significant production growth in the 1980s over the 1970s, rape (*Brassica napus*) seed (canola) has surpassed it in terms of world production in the early 1990s. Furthermore, sunflower seed is close behind. This change in world ranking may be attributable to the emergence of health concerns in the industrial countries. Since the mid-1970s, edible groundnut has increased in importance for both domestic consumption and the export trade. The export market has become more concentrated in the 1980s while the import market is less concentrated. While world harvested area changed very little from the 1970s to the 1980s, there were definite regional and subregional shifts. Asia and, in particular, the People's Republic of China increased their shares significantly, while Africa's share decreased. A similar picture was seen for yield. Asia and the People's Republic of China had the largest yield increases while Africa's yield declined from the 1970s to the 1980s. However, West Africa showed a modest increase.*

Résumé

***Arachide—production, utilisation et commerce au cours des années 1980:** L'arachide (*Arachis hypogaea*) est l'une des principales cultures oléagineuses du monde. Bien que l'arachide ait connu une augmentation très nette de production au cours des années 1980 par rapport aux années 1970, le colza (*Brassica napus*) l'a surpassée au niveau de la production mondiale au cours des premières années 1990. En outre, la graine de tournesol la suit de près. Ce changement du rang mondial peut être attribuable aux préoccupations sanitaires dans les pays industrialisés. Depuis la mi-1970, l'arachide de bouche a revêtu une importance croissante tant pour la consommation intérieure que pour le commerce d'exportation. Le marché d'exportation est devenu plus concentré au cours des années 1980, tandis que le marché d'importation est moins concentré. Même si la superficie consacrée à l'arachide dans le monde n'a que peu changé des années 1970 aux années 1980, il y a eu des changements régionaux très marqués. L'Asie et, plus particulièrement la Chine, ont augmenté leurs parts à un degré significatif, tandis que la part de l'Afrique a diminué. Un tableau analogue peut se voir en ce qui concerne le rendement. L'Asie et, particulièrement la Chine, ont connu les augmentations les plus importantes de rendement, tandis que le rendement de l'Afrique a baissé des années 1970 aux années 1980. Toutefois, l'Afrique occidentale a légèrement augmenté sa production de l'arachide.*

1. Associate Professor, Postdoctoral Associate, and Professor, Department of Agricultural Economics, Georgia Experiment Station, University of Georgia, Griffin, GA 30223-1797, USA.

This publication was made possible in part through the support provided by the Georgia Agricultural Commodity Commission for Peanuts and by the Office of Agriculture, Bureau of Research and Development, U.S. Agency for International Development, under Grant No. DAN-4048-G-00-0041-00.

Fletcher, S.M., Ping Zhang, and **Carley, D.H.** 1992. Groundnuts: production, utilization, and trade in the 1980s. Pages 17–32 *in* Groundnut – a global perspective: proceedings of an international workshop, 25–29 Nov 1991, ICRISAT Center, India (Nigam, S.N., ed.). Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Groundnut (*Arachis hypogaea*) is an annual soil-enriching legume native to South America. The plants were carried to Africa and China by early explorers and missionaries. During early colonial days in the United States of America, the groundnut was introduced from Africa. Presently, groundnut production can be found on six continents, although four continents account for most production. Groundnut is one of the principal oilseeds in the world. Until the mid-1980s, groundnut ranked third behind soybeans (*Glycine max*) and cotton (*Gossypium* spp) seed, but now rape (*Bassica napus*) seed (canola) has passed groundnut in terms of world production, closely followed by sunflower (*Helianthus annuus*) seed. The emergence of rape seed and sunflower seed may be attributed to health concerns by the industrial countries and the European Economic Community's (EEC) Common Agricultural Policy (CAP).

The focus of this paper is to provide an overview of world groundnut production, utilization, and trade in the 1980s. The data source is the "Foreign Production, Supply & Distribution of Agricultural Commodities" from the Foreign Agricultural Service, the United States Department of Agriculture (USDA). Data are derived from counselor and attaché reports, official statistics from such sources as the Food and Agriculture Organization of the United Nations (FAO), and USDA estimates. The analysis will be delineated into three geographic sections. The first section will present the world picture for the 1980s. The succeeding section will divide the world into regional classifications based on the regional reports to be presented at this Workshop. Finally, the last section deals with key individual countries. (As further information for the reader, mean values for production, utilization, and trade for the 1980s for all countries used in the analysis are presented in Appendix 1.)

World

World groundnut production has shown a continual increase with a major increase in the 1980s (Table 1). The average production for 1966–68 was 16 435 000 t. Average production in the 1970s was 16 948 600 t, an increase of approximately 500 000 t. In contrast, average production in the 1980s was 19 809 800 t, almost a 17% increase over the 1970s average production. Preliminary 1990s data show no major differences from production in the late 1980s. This significant increase in the 1980s is attributable to yield increases, rather than harvested area. Harvested area for 1966–68 was 18.7 million ha while there were 18.2 million ha in the 1970s, and 18.3 million ha in the 1980s. In contrast, world yield increased from 0.88 t ha^{-1} in 1966–68 to 0.93 t ha^{-1} in the 1970s, a 6% increase.

Table 1. World groundnut harvested area, yield, production, utilization, and exports, 1980–89.

Year	Harvested area ('000 ha)	Yield (t ha^{-1})	Production ('000 t)	Utilization ('000 t) Crushed	Food use	Other use	Total	Exports ('000 t)
1980	17 763	0.92	16 271	8 577	5827	2004	16 408	1142
1981	18 531	1.07	19 832	11 043	6273	2371	19 687	1007
1982	17 951	0.97	17 435	9 327	6128	2051	17 506	1088
1983	17 790	1.05	18 738	10 100	6438	2254	18 792	1003
1984	17 659	1.11	19 684	10 586	6829	1964	19 379	1097
1985	17 837	1.12	19 990	10 456	7441	2220	20 117	1365
1986	18 366	1.11	20 383	10 885	7507	1948	20 340	1281
1987	18 225	1.11	20 317	10 435	7812	2003	20 250	1297
1988	19 776	1.18	23 369	13 107	8103	2329	23 539	1156
1989	19 361	1.14	22 079	12 034	7884	2294	22 212	1206
Average 1980s	18 325.9	1.08	19 809.8	10 655.0	7024.2	2143.8	19 823.0	1164.2
Average 1970s	18 237.3	0.93	16 948.6	9 839.6	5245.1	1854.2	16 939.0	1105.7
Change	88.6	0.15	2 861.2	815.4	1779.1	289.6	2 884.0	58.5
Change (%)	0.5	16.05	16.9	8.3	33.9	15.6	17.0	5.3

The 1980s experienced another 16% increase in yield over the 1970s.

Groundnuts are utilized in several ways. The groundnut is crushed for oil and meal. The edible oil is an important source for human consumption, especially in Asia and Africa. The meal is used for livestock feed. Groundnut is also used directly for food in its primary form among industrial countries such as the USA, Canada, and the EEC. Finally, the groundnut can be exported or imported, carried over for use in the following year, used as seed, and used for industrial purposes.

The domestic utilization for crushing and food use has shown an increase in the 1980s (Table 1). The major increase was in food use with a 34% increase over the 1970s average use. Closer examination of these data reveals a continuing shift in utilization from crushing to food. For example, 58% of the utilization during the 1970s was for crushing while in the 1980s this dropped to 53.5%. The opposite was observed for food use where it increased from 31% in the 1970s to approximately 35.5% in the 1980s. The other use category (other than crushing and food) showed no change in its share between the two time periods.

Groundnut trade has changed character since the 1960s and may change again in the 1990s. In the 1960s and early 1970s groundnut oil was the major item traded with edible groundnut trade being negligible. Since that period, the reverse has occurred. Edible groundnuts drive the world groundnut trade while groundnut oil is of minor importance. However, overall world groundnut trade is increasing only modestly, approximately 5% in the 1980s over the 1970s. Furthermore, the share of production exported has fallen by about 10 percentage points from the 1970s to the 1980s.

This picture painted for the 1980s could change dramatically in the 1990s, as a result of General Agreement on Tariffs and Trade (GATT) negotiations. The stated purpose of the GATT talks is to "level the playing field." That is, producer and consumer subsidies as well as trade restrictions must be eliminated or at least reduced. This will have an impact on groundnut production and trade. For example, the USA has an import restriction on groundnuts. A GATT agreement could eliminate the import restriction and open the U.S. domestic groundnut market to other countries. India has a self-sufficiency policy on vegetable oil, of which groundnut is a major component. This policy restricts imports of other oils like palm oil. In addition, India provides producer subsidies as do many other countries. Under a new GATT agreement, markets would be opened up and cost of production could change.

A GATT agreement probably will not treat all countries equally. Less-developed and developing countries would be given a longer time frame relative to the developed countries in meeting the targets. In addition to these issues, not all groundnut producing and consuming countries are members of GATT. For example, the USA, India, and Argentina are members, but China and most African countries are not. Countries do not want to be placed at a competitive disadvantage. Thus, more questions are raised than answered.

Regional

Groundnut geographic classification is delineated into six regions: the Americas, Africa, Asia, Near East Asia, Europe, and Oceania (Table 2). The Americas, Africa, Asia, and Europe are subdivided into subregions as seen in Table 2.

While world groundnut production has increased, there have been regional variations (Table 3). The increase in production is primarily in Asia with east Asia being the major contributor. Asia increased its 1980s production by 41% over the 1970s, while east Asia's production increased by 113% with China being the major contributor. In contrast, Africa had a 17% decrease in production from the 1970s to 1980s with eastern and southern Africa being the main subregions contributing to this loss. The drop in production in the Americas was due to reductions in South America while North America (USA) had a very small increase (1%). These changes in production imply a change in the world production distribution. That is, the Americas accounted for only 12% of the world production in the 1980s, but 16% in the 1970s. Africa's share dropped from 27% to 19% while Asia's share increased from 56% to 67%. However, within Asia, East Asia's share increased from 14% to 26% while southwestern Asia's share decreased from 34% to 33%.

These shifts in production are due to changes in harvested area and yield. While the world harvested area increased by only 0.5%, there were regional and subregional readjustments (Table 4). Asia had an increase in harvested area (12%) with east Asia being the major contributor. Africa had a 13% drop in harvested area while the Americas had a 25% decrease with South America accounting for the decrease. Asia accounted for 64% (58% for the 1970s) of world harvested area in the 1980s with all three subregions

Table 2. Groundnut geographic classification, by region and by country.

America		Africa		
South America	North America	Eastern Africa	Southern Africa	West Africa
Argentina	Canada	Burundi	Madagascar	Benin
Bolivia	Mexico	Sudan	Malawi	Burkina Faso
Brazil	United States	Tanzania	Mozambique	Central African Republic
Colombia		Uganda	South Africa	Cameroon
Dominica			Zambia	Chad
Ecuador			Zimbabwe	Côte d'Ivoire
Paraguay				Gambia
Trinidad and Tobago				Ghana
Uruguay				Guinea
Venezuela				Mali
				Niger
				Nigeria
				Guinea-Bissau
				Senegal
				Togo
				Zaire

Asia			Near East Asia & Mediterranean
East Asia	Southeast Asia	Southwest Asia	
China	Bangladesh	India	Egypt
Hong Kong	Indonesia	Pakistan	Israel
Japan	Malaysia		Jordan
Korea	Myanmar		Morocco
Taiwan	Philippines		Syria
	Singapore		Turkey
	Thailand		
	Vietnam		

Europe			Oceania
East Europe	EEC	West Europe	
Czechoslovakia	Belgium	Austria	Australia
Hungary	France	Norway	New Zealand
CIS (formerly USSR)	Germany	Sweden	
Yugoslavia	Luxembourg	Switzerland	
	Netherlands		
	Portugal		
	Spain		
	United Kingdom		

showing an increase. Africa's share was 30% (34% for the 1970s) while the Americas was 6% (8% for the 1970s).

Regional and subregional yield variations existed between the 1970s and 1980s (Table 5). Asia had the largest percentage yield increase (26%). Within Asia, East Asia had the largest yield increase, 0.57 t ha^{-1}, while southwestern Asia had the lowest, 0.07 t ha^{-1}. Africa, on average, had a drop in yield but West Africa had a small increase while eastern and southern Africa had declines. The Americas had a yield increase that was accounted for by South America while North America (USA) had a small decrease.

Table 3. World groundnut production by region, 1980–89 ('000 t).

Regions	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	Average 1980s	Average 1970s	Change	Change (%)
Americas														
N. America	1105	1879	1610	1555	2054	1935	1737	1751	1910	1929	1746.5	1735.0	11.5	0.7
S. America	647	676	584	642	703	750	812	713	488	616	663.1	995.0	-331.9	-33.4
Subtotal	1752	2555	2194	2197	2757	2685	2549	2464	2398	2545	2409.6	2730.0	-320.4	-11.7
Africa														
E. Africa	881	928	695	612	585	475	610	685	700	648	681.9	1043.0	-361.1	-34.6
S. Africa	763	527	416	276	431	360	507	471	476	498	472.5	780.4	-307.9	-39.5
W. Africa	2321	2658	2844	2489	2369	2471	2775	2978	2752	2693	2635.0	2761.9	-126.9	-4.6
Subtotal	3965	4113	3955	3377	3385	3306	3892	4134	3928	3839	3789.4	4585.3	-795.9	-17.4
Asia														
E. Asia	3762	3994	4053	4116	4981	6824	6052	6370	5847	5470	5146.9	2418.5	2728.4	112.8
S.E. Asia	1529	1641	1680	1677	1847	1774	1727	1750	1849	1864	1733.8	1361.3	372.6	27.4
S.W. Asia	5062	7295	5366	7174	6505	5183	5950	5352	9078	8080	6504.5	5708.6	795.9	13.9
Subtotal	10353	12930	11099	12967	13333	13781	13729	13472	16774	15414	13385.2	9488.4	3896.8	41.1
Near East[1]	150	168	158	144	160	167	158	200	231	237	177.3	98.1	79.2	80.7
Europe	8	8	6	6	7	8	10	8	6	7	7.4	9.1	-1.7	-18.9
Oceania	43	58	23	47	42	43	45	39	32	37	40.9	38.3	2.6	6.9
World	16271	19832	17435	18738	19684	19990	20383	20317	23369	22079	19809.8	16948.6	2861.2	16.9

1. Near East includes Mediterranean countries (see Table 2).

Table 4. World groundnut harvested area by region, 1980–89 ('000 ha).

Regions	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	Average 1980s	Average 1970s	Change	Change (%)
Americas														
N. America	606	649	562	601	658	637	666	716	744	748	658.7	646.9	11.8	1.8
S. America	525	502	424	386	429	420	464	375	330	347	420.2	786.3	-366.1	-46.6
Subtotal	1131	1151	986	987	1087	1057	1130	1091	1074	1095	1078.9	1433.1	-354.2	-24.7
Africa														
E. Africa	1128	1243	1028	1018	987	652	808.	858	858	833	941.3	1155.4	-214.1	-18.5
S. Africa	1029	967	912	717	713	716	839	775	755	799	822.2	1108.0	-285.8	-25.8
W. Africa	3770	3604	3727	3595	3480	3216	3609	3852	3885	3690	3642.8	3974.0	-331.2	-8.3
Subtotal	5927	5814	5667	5330	5180	4584	5256	5485	5498	5322	5406.3	6237.4	-831.1	-13.3
Asia														
E. Asia	2435	2565	2503	2295	2513	3406	3340	3126	2990	3035	2820.8	1952.5	868.3	44.5
S.E. Asia	1310	1390	1384	1458	1543	1509	1481	1495	1594	1622	1478.6	1361.5	117.1	8.6
S.W. Asia	6848	7489	7284	7611	7226	7175	7045	6911	8498	8170	7425.7	7163.1	262.6	3.7
Subtotal	10593	11444	11171	11364	11282	12090	11866	11532	13082	12827	11725.1	10477.1	1248.0	11.9
Near East[1]	81	85	87	73	76	73	73	82	91	94	81.5	55.8	25.8	46.2
Europe	4	4	4	4	4	4	4	3	2	2	3.5	4.4	-0.9	-20.0
Oceania	27	33	36	32	30	29	37	32	29	21	30.6	29.5	1.1	3.7
World	17763	18531	17951	17790	17659	17837	18366	18225	19776	19361	18325.9	18237.3	88.6	0.5

1. Near East includes Mediterranean countries (see Table 2).

Table 5. World groundnut yield, 1980–89 (t ha⁻¹).

Regions	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	Average 1980s	Average 1970s	Change	Change (%)
Americas														
N. America	1.82	2.90	2.86	2.59	3.12	3.04	2.61	2.45	2.57	2.58	2.65	2.68	-0.03	-1.1
S. America	1.23	1.35	1.38	1.66	1.64	1.79	1.75	1.90	1.48	1.78	1.59	1.27	0.33	26.0
Average	1.55	2.22	2.23	2.23	2.54	2.54	2.26	2.26	2.23	2.32	2.24	1.91	0.33	17.1
Africa														
E. Africa	0.78	0.75	0.68	0.60	0.59	0.73	0.75	0.80	0.82	0.78	0.73	0.90	-0.18	-19.4
S. Africa	0.74	0.54	0.46	0.38	0.60	0.50	0.60	0.61	0.63	0.62	0.57	0.70	-0.13	-19.1
W. Africa	0.62	0.74	0.76	0.69	0.68	0.77	0.77	0.77	0.71	0.73	0.72	0.69	0.03	4.1
Average	0.67	0.71	0.70	0.63	0.65	0.72	0.74	0.75	0.71	0.72	0.70	0.74	-0.03	-4.6
Asia														
E. Asia	1.54	1.56	1.62	1.79	1.98	2.00	1.81	2.04	1.96	1.80	1.81	1.24	0.57	46.2
S.E. Asia	1.17	1.18	1.21	1.15	1.20	1.18	1.17	1.17	1.16	1.15	1.17	1.00	0.17	17.3
S.W. Asia	0.74	0.97	0.74	0.94	0.90	0.72	0.84	0.77	1.07	0.99	0.87	0.80	0.07	9.1
Average	0.98	1.13	0.99	1.14	1.18	1.14	1.16	1.17	1.28	1.20	1.14	0.91	0.23	25.7
Near East[1]	1.85	1.98	1.82	1.97	2.11	2.29	2.16	2.44	2.54	2.52	2.17	1.76	0.41	23.1
Europe	2.00	2.00	1.50	1.50	1.75	2.00	2.50	2.67	3.00	3.50	2.24	2.09	0.16	7.5
Oceania	1.59	1.76	0.64	1.47	1.40	1.48	1.22	1.22	1.10	1.76	1.36	1.30	0.07	5.2
World	0.92	1.07	0.97	1.05	1.11	1.12	1.11	1.11	1.18	1.14	1.08	0.93	0.15	16.1

1. Near East includes Mediterranean countries (see Table 2).

While world groundnut domestic utilization increased by 17% from the 1970s to the 1980s, not all regions or subregions experienced similar growth (Table 6). Asia was the only major region to show a growth with East Asia being the main contributor. Africa had a 12% decrease overall, while West Africa had a small increase. The Americas had essentially no change due to an increase for North America offsetting a decrease for South America. Europe had a 25% decrease, accounted for by the EEC and western Europe. The European decline is attributable to its decreased use of groundnut oil.

The distribution of the groundnut domestic utilization between crushed and food use is shown in Tables 7 and 8. The Americas decreased their share of crushed groundnut from 47% in the 1970s to 30% in the 1980s. Within Africa, West Africa had the largest decline in crushing, most of this going to food use. Within Asia, East Asia had an increase in crushing and a decrease in food use. Southwestern Asia had little change between the 1970s and 1980s. Europe had a tremendous switch from crushing to food use.

Regional and subregional trade information is provided in Tables 9 and 10. Asia experienced the largest increase in groundnut exports (177%). Once again, East Asia (China) accounted for the increase. Southwestern Asia (India) experienced a decline (40%) in exports from the 1970s to the 1980s. All African subregions experienced declines in export trade, which is due to the decline in groundnut oil trade. While the Americas export trade growth matched the world growth, it is clear that North America (USA) had a decline. This was due to the number of droughts in the USA during the 1980s that restricted USA's exports. In terms of the world groundnut export trade shares, Asia accounted for 37% during the 1980s, which is a tremendous increase over the 1970s value of 14%. This resulted from China's entry into the world market. Africa's share dropped from 40% to 15% while the Americas had basically no change (42%). In terms of imports, the Americas experienced growth mostly due to Canada. Growth in Asia was in Hong Kong, Japan, and Southeast Asia. Europe's decline is due to the reduction in groundnut oil imports that more than offset Europe's increased edible groundnuts. In the 1980s, the Americas accounted for 11% of world imports, Africa 3%, Asia 27%, and Europe 58%.

Table 6. World groundnut domestic utilization, by region, 1980–89 ('000 t).

Regions	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	Average 1980s	Average 1970s	Change	Change (%)
Americas														
N. America	1260	1543	1343	1423	1388	1828	1478	1618	1674	1688	1524.3	1140.5	383.8	33.7
S. America	531	628	463	507	566	469	675	500	429	471	523.9	921.1	-397.2	-43.1
Subtotal	1791	2171	1806	1930	1954	2297	2153	2118	2103	2159	2048.2	2061.6	-13.4	-0.7
Africa														
E. Africa	748	797	625	561	570	464	600	610	650	623	624.8	881.9	-257.1	-29.2
S. Africa	637	554	455	288	378	334	451	421	410	422	435.0	697.0	-262.0	-37.6
W. Africa	2295	2594	2691	2496	2346	2452	2756	2862	2758	2679	2592.9	2575.6	17.3	0.7
Subtotal	3680	3945	3771	3345	3294	3250	3807	3893	3818	3724	3652.7	4154.5	-501.8	-12.1
Asia														
E. Asia	3574	3968	3954	4043	4902	6642	5779	6141	5747	5429	5017.9	2474.1	2543.8	102.8
S.E. Asia	1534	1708	1706	1700	1853	1824	1836	1874	1932	1953	1792.0	1360.0	432.0	31.8
S.W. Asia	5091	7049	5531	7014	6565	5268	5910	5342	9008	8010	6478.8	5638.8	840.1	14.9
Subtotal	10199	12725	11191	12757	13320	13734	13525	13357	16687	15392	13288.7	9472.9	3815.8	40.3
Near East[1]	122	132	127	119	141	149	139	181	214	217	154.1	79.4	74.7	94.1
Europe														
EEC	470	537	468	473	487	511	529	517	529	545	506.6	728.9	-222.3	-30.5
E. Europe	73	86	73	77	92	81	78	73	79	69	78.1	44.4	33.7	76.0
W. Europe	27	28	32	30	36	43	52	55	54	54	41.1	60.6	-19.5	-32.2
Subtotal	570	651	573	580	615	635	659	645	662	668	625.8	833.9	-208.1	-25.0
Oceania	46	63	38	61	55	52	57	56	55	52	53.5	36.8	16.8	45.6
World	16408	19687	17506	18792	19379	20117	20340	20250	23539	22212	19823.0	16939.0	2884.0	17.0

1. Near East includes Mediterranean countries (see Table 2).

Table 7. Crushed groundnut as percentage of the total domestic utilization, by region, 1980–89.

Regions	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	Average 1980s	Average 1970s	Change	Change (%)
Americas														
N. America	16.19	16.98	11.62	12.44	20.46	20.24	15.83	15.76	22.10	13.68	16.53	24.36	-7.83	-32.14
S. America	73.45	82.17	75.81	65.48	73.85	62.90	70.81	54.40	47.79	51.38	65.80	80.81	-15.00	-18.57
Average	33.17	35.84	28.07	26.37	35.93	28.95	33.07	24.88	27.34	21.91	29.55	46.55	-17.00	-36.51
Africa														
E. Africa	58.42	61.86	44.96	44.74	42.28	40.09	42.67	40.33	37.85	42.70	45.59	48.19	-2.60	-5.40
S. Africa	30.46	33.57	27.47	31.25	36.24	29.34	46.78	38.95	38.54	38.63	35.12	36.47	-1.35	-3.69
W. Africa	41.70	49.34	49.13	40.30	37.72	42.90	45.97	44.20	42.68	44.46	43.84	57.88	-14.04	-24.26
Average	43.15	49.66	45.82	40.27	38.34	41.11	45.55	43.03	41.41	43.50	43.18	52.31	-9.13	-17.45
Asia														
E. Asia	47.20	48.11	48.71	48.01	51.96	52.60	52.34	52.61	52.38	51.59	50.55	45.16	5.39	11.94
S.E. Asia	32.27	34.54	33.94	36.59	38.48	34.87	33.99	32.44	33.44	33.08	34.36	35.46	-1.10	-3.10
S.W. Asia	79.73	79.00	79.86	79.04	79.83	79.92	79.36	79.65	79.65	79.53	79.56	79.48	0.07	0.09
Average	61.19	63.40	61.85	63.55	63.82	60.73	61.66	60.60	64.91	63.78	62.55	64.18	-1.63	-2.54
Near East[1]	6.56	11.36	14.17	12.61	7.09	13.42	14.39	11.05	9.35	9.22	10.92	20.53	-9.61	-46.79
Europe														
EEC	26.88	36.80	27.09	22.98	19.07	14.89	11.78	18.96	15.26	15.53	20.92	53.66	-32.74	-61.01
E. Europe	9.59	9.30	12.33	5.19	7.61	12.35	10.26	10.96	10.13	11.59	9.93	3.59	6.34	176.82
Average	24.39	32.72	24.78	20.34	17.07	14.33	11.38	17.67	14.35	14.82	19.19	53.37	-34.18	-64.05
Oceania	15.22	15.87	26.32	6.56	9.09	7.69	8.77	8.93	9.09	9.62	11.72	19.10	-7.39	-38.68
World	52.27	56.09	53.28	53.75	54.63	51.98	53.52	51.53	55.68	54.18	53.69	58.07	-4.38	-7.54

1. Near East includes Mediterranean countries (see Table 2).

Table 8. Food use as percentage of the total domestic groundnut utilization, by region, 1980–89.

Regions	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	Average 1980s	Average 1970s	Change	Change (%)
Americas														
N. America	65.08	59.36	72.45	68.87	72.26	58.04	75.24	69.10	71.57	74.11	68.61	64.12	4.49	7.00
S. America	15.07	10.99	15.12	25.25	15.72	21.54	20.74	31.40	37.06	33.97	22.69	10.47	12.22	116.69
Average	50.25	45.37	57.75	57.41	55.89	50.59	58.15	60.20	64.53	65.35	56.55	43.01	13.54	31.47
Africa														
E. Africa	34.22	31.24	49.44	48.31	51.58	54.09	52.17	54.43	55.69	51.36	48.25	38.75	9.50	24.53
S. Africa	53.06	50.54	52.75	60.76	55.56	63.17	48.56	55.58	56.83	56.64	55.34	49.94	5.41	10.83
W. Africa	43.09	37.86	35.64	45.39	49.83	44.41	44.12	46.16	48.26	46.59	44.13	32.88	11.25	34.22
Average	43.02	38.30	39.99	47.20	50.79	47.72	45.92	48.47	50.45	48.52	46.04	36.95	9.09	24.59
Asia														
E. Asia	41.83	42.31	42.51	42.20	39.82	39.27	39.26	39.64	39.20	39.44	40.55	42.55	-2.00	-4.71
S.E. Asia	59.00	57.03	54.22	53.00	51.86	56.47	57.08	58.22	57.45	57.86	56.22	54.45	1.76	3.24
S.W. Asia	7.41	7.59	7.58	7.71	7.31	7.33	7.60	7.34	7.28	7.39	7.45	8.19	-0.74	-9.01
Average	27.23	25.05	27.03	24.68	25.47	29.30	27.84	29.33	24.08	25.10	26.51	23.79	2.72	11.42
Near East[1]	86.89	81.06	79.53	79.83	87.23	81.21	80.58	85.08	87.85	88.02	83.73	72.23	11.49	15.91
Europe														
EEC	74.04	63.31	74.57	78.01	82.55	88.06	92.82	86.27	89.79	89.36	81.88	45.76	36.12	78.94
E. Europe	90.41	90.70	87.67	94.81	92.39	87.65	89.74	89.04	89.87	88.41	90.07	96.41	-6.34	-6.58
W. Europe	40.74	46.43	37.50	36.67	36.11	32.56	30.77	30.91	31.48	31.48	35.46	15.00	20.47	136.49
Average	74.56	66.21	74.17	78.10	81.30	84.25	87.56	81.86	85.05	84.58	79.76	46.28	33.49	72.36
Oceania	78.26	80.95	68.42	90.16	87.27	92.31	91.23	91.07	90.91	90.38	86.10	74.95	11.14	14.87
World	35.51	31.86	35.01	34.26	35.24	36.99	36.91	38.58	34.42	35.49	35.43	31.04	4.39	14.13

1. Near East includes Mediterranean countries (see Table 2).

Table 9. World groundnut exports by region, 1980–89 ('000 t).

Regions	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	Average 1980s	Average 1970s	Change	Change (%)
Americas														
N. America	229	262	310	338	391	474	302	281	313	375	327.5	365.3	-37.8	-10.3
S. America	123	84	137	139	154	216	201	177	126	173	153.0	89.4	63.6	71.2
Subtotal	352	346	447	477	545	690	503	458	439	548	480.5	454.6	25.9	5.7
Africa														
E. Africa	133	131	70	51	15	11	10	75	50	25	57.1	161.1	-104.0	-64.6
S. Africa	71	57	14	10	61	42	42	78	69	76	52.0	94.0	-42.0	-44.7
W. Africa	26	64	83	63	53	62	56	73	72	74	62.6	191.0	-128.4	-67.2
Subtotal	230	252	167	124	129	115	108	226	191	175	171.7	446.1	-274.4	-61.5
Asia														
E. Asia	359	232	289	231	243	387	462	401	289	242	313.5	43.7	269.8	616.6
S.E. Asia	58	57	92	54	77	88	83	95	72	73	74.9	37.1	37.8	101.8
S.W. Asia	71	46	35	60	40	15	40	10	70	70	45.7	76.1	-30.4	-40.0
Subtotal	488	335	416	345	360	490	585	506	431	385	434.1	157.0	277.1	176.5
Near East[1]	30	35	29	22	22	22	26	24	22	25	25.7	18.7	7.0	37.1
Europe	34	33	24	30	36	45	56	79	71	71	47.9	26.4	21.5	81.6
Oceania	8	6	5	5	5	3	3	4	2	2	4.3	2.9	1.4	49.6
World	1142	1007	1088	1003	1097	1365	1281	1297	1156	1206	1164.2	1105.7	58.5	5.3

1. Near East includes Mediterranean countries (see Table 2).

Table 10. World groundnut imports by region, 1980–89 ('000 t).

Regions	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	Average 1980s	Average 1970s	Change	Change (%)
Americas														
N. America	285	84	88	92	92	112	109	70	75	75	108.2	85.3	23.0	26.9
S. America	6	20	5	21	21	11	7	14	15	15	13.5	17.5	-4.0	-22.9
Subtotal	291	104	93	113	113	123	116	84	90	90	121.7	102.7	19.0	18.4
Africa	0	0	33	30	40	57	74	36	34	36	34.0	4.1	29.9	724.2
Asia														
E. Asia	180	194	188	160	160	211	196	184	184	200	185.7	102.4	83.3	81.4
S.E. Asia	61	124	117	83	93	147	178	203	160	160	132.6	22.4	110.2	492.6
Subtotal	241	318	305	243	253	358	374	387	344	360	318.3	124.7	193.6	155.2
Near East[1]	2	2	1	2	2	2	5	5	5	5	3.1	0	3.1	
Europe														
EEC	499	558	488	506	525	586	557	577	595	610	550.1	747.9	-197.8	-26.4
E. Europe	72	85	72	76	90	79	75	71	77	67	76.4	43.4	33.0	76.1
W. Europe	27	28	32	30	36	43	52	55	54	54	41.1	60.6	-19.5	-32.2
Subtotal	598	671	592	612	651	708	684	703	726	731	667.6	851.9	-184.3	-21.6
Oceania	9	13	16	20	12	12	15	21	25	17	16.0	2.5	13.5	540.0
World	1141	1108	1040	1020	1071	1260	1268	1236	1224	1239	1160.7	1086.0	74.7	6.9

1. Near East includes Mediterranean countries (see Table 2).

Table 11. Top ten countries in world groundnut production, utilization, and trade in 1970s and 1980s.

Production		Harvested (ha)		Domestic utilization		Exports		Imports	
1970s	1980s	1970s	1980s	1970s	1980s	1970s	1980s	1970s	1980s
India	India	India	India	India	India	USA	USA	France	UK
China	China	China	China	China	China	Sudan	China	UK	Netherlands
USA	USA	Senegal	Senegal	USA	USA	India	Argentina	Italy	Japan
Senegal	Indonesia	Nigeria	Sudan	Senegal	Indonesia	South Africa	Sudan	Japan	Germany
Sudan	Senegal	Sudan	Nigeria	Sudan	Senegal	Gambia	Hong Kong	Canada	Canada
Indonesia	Myanmar	Myanmar	USA	Indonesia	Myanmar	Brazil	India	Netherlands	France
Nigeria	Sudan	USA	Myanmar	Nigeria	Nigeria	Senegal	Gambia	Germany	Singapore
Brazil	Nigeria	Indonesia	Indonesia	Brazil	Sudan	Nigeria	Vietnam	Portugal	CIS (formerly USSR)
Argentina	Zaire	Zaire	Zaire	Myanmar	Zaire	China	Netherlands	Switzerland	Hong Kong
Myanmar	Argentina	Argentina	Cameroon	Argentina	Brazil	Argentina	South Africa	CIS (formerly USSR)	Indonesia

Individual Countries

This section examines the top ten countries in world groundnut production, utilization, and trade. Table 11 provides the rankings for each category for the 1970s and 1980s. The rankings differ slightly between the two time periods, except for export trade.

India and China increased their share of the world groundnut production from approximately 46% in the 1970s to 57% in the 1980s (Table 12). If U.S. produc-

Table 12. Groundnut production and harvested area by the major producers, 1980–89.

Regions	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	Average 1980s	Average 1970s	Change	Change (%)
Production ('000 t):														
India	5005	7223	5282	7086	6436	5120	5875	5300	9000	8000	6432.7	5652.1	780.6	13.8
China	3600	3826	3916	3951	4185	6664	5882	6170	5693	5300	4918.7	2233.4	2685.3	120.2
USA	1045	1806	1560	1495	1999	1870	1677	1640	1806	1828	1672.6	1680.5	-7.9	-0.5
Indonesia	791	728	795	747	755	780	750	786	830	840	780.2	639.0	141.2	22.1
Senegal	521	878	1109	568	560	587	817	932	690	738	740.0	882.6	-142.6	-16.2
Myanmar	431	564	541	532	667	560	544	519	565	575	549.8	406.5	143.3	35.3
Sudan	707	740	497	413	390	275	380	435	450	400	468.7	796.5	-327.8	-41.2
Nigeria	530	428	396	591	500	400	400	475	350	350	442.0	511.4	-69.4	-13.6
Zaire	320	347	357	367	375	375	380	380	380	380	366.1	294.4	71.7	24.4
Argentina	243	270	250	329	270	439	518	450	243	370	338.2	431.3	-93.1	-21.6
Others	3078	3022	2732	2659	3547	2920	3160	3230	3362	3298	3180.8	3421.0	-320.2	-9.4
Harvested area ('000 ha):														
India	6801	7429	7215	7539	7168	7120	6982	6844	8430	8100	7362.8	7221.1	241.7	3.4
China	2339	2472	2416	2201	2421	3318	3253	3022	2914	2956	2731.2	1839.3	891.9	48.5
USA	566	602	517	556	618	594	621	626	659	663	602.2	608.4	-6.2	-1.0
Indonesia	508	461	480	523	510	515	516	550	605	615	528.3	462.1	66.2	14.3
Senegal	1064	1080	1121	937	874	607	808	846	903	790	903.0	1130.5	-227.5	-20.1
Myanmar	514	598	571	561	647	595	564	537	585	600	577.2	613.6	-36.4	-5.9
Sudan	894	998	782	770	735	400	540	575	575	550	68.9	834.6	-152.7	-18.3
Nigeria	650	479	600	600	550	520	660	800	700	700	625.9	906.3	-280.4	-30.9
Zaire	480	496	510	524	524	524	524	530	530	530	517.2	453.9	63.3	14.0
Argentina	197	166	125	146	143	168	233	192	150	160	168.0	355.9	-187.9	-52.8
Others	3750	3750	3614	3433	3469	3476	3665	3703	3725	3697	3628.2	3911.7	-283.5	-7.2

Table 13. Yield in the major groundnut producing countries, 1980–89 (t ha^{-1}).

Regions	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	Average 1980s	Average 1970s	Change	Change (%)
India	0.74	0.97	0.73	0.94	0.90	0.72	0.84	0.77	1.07	0.99	0.87	0.79	0.07	9.31
China	1.54	1.55	1.62	1.80	1.73	2.01	1.81	2.04	1.95	1.79	1.78	1.21	0.57	47.16
USA	1.85	3.00	3.02	2.69	3.23	3.15	2.70	2.62	2.74	2.76	2.78	2.76	0.01	0.52
Indonesia	1.56	1.58	1.66	1.43	1.48	1.51	1.45	1.43	1.37	1.37	1.48	1.38	0.11	7.90
Senegal	0.49	0.81	0.99	0.61	0.64	0.97	1.01	1.10	0.76	0.93	0.83	0.77	0.06	8.29
Myanmar	0.84	0.94	0.95	0.95	1.03	0.94	0.96	0.97	0.97	0.96	0.95	0.67	0.29	42.93
Sudan	0.79	0.74	0.64	0.54	0.53	0.69	0.70	0.76	0.78	0.73	0.69	0.95	-0.26	-27.60
Nigeria	0.82	0.89	0.66	0.99	0.91	0.77	0.61	0.59	0.50	0.50	0.72	0.58	0.15	25.12
Zaire	0.67	0.70	0.70	0.70	0.72	0.72	0.73	0.72	0.72	0.72	0.71	0.65	0.06	9.00
Argentina	1.23	1.63	2.00	2.25	1.89	2.61	2.22	2.34	1.62	2.31	2.01	1.21	0.80	66.51
Others	0.82	0.81	0.76	0.77	1.02	0.84	0.86	0.87	0.90	0.89	0.85	0.86	-0.01	-0.78
World	0.92	1.07	0.97	1.05	1.11	1.12	1.11	1.11	1.18	1.14	1.08	0.93	0.15	16.05

tion is included, the shares increase to 56% and 65%, respectively. The other seven top countries' shares are individually less than 4% of the world production. China was the only country that had a significant increase in world production share between the two time periods. There was little change in the other countries. China also experienced a significant yield increase, second only to Argentina (Table 13). The USA showed little change from the 1970s to the 1980s.

Table 14. Domestic groundnut utilization by the major consuming countries, 1980–89 ('000 t).

Regions	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	Average 1980s	Average 1970s	Change	Change (%)
India	5034	6977	5447	6926	6496	5205	5835	5290	8930	7930	6407.0	5582.3	824.8	14.8
China	3295	3669	3684	3742	4602	6332	5484	5811	5447	5100	4716.6	2192.1	2524.5	115.2
USA	1097	1390	1203	1274	1241	1661	1305	1438	1497	1513	1361.9	1303.8	58.2	4.5
Indonesia	804	817	854	775	777	823	819	825	840	857	819.1	632.9	186.2	29.4
Senegal	518	872	1039	622	560	585	842	887	764	777	746.6	839.4	-92.8	-11.1
Myanmar	431	564	541	532	667	560	544	519	565	575	549.8	406.5	143.3	35.3
Nigeria	530	428	396	591	530	443	415	469	349	360	451.1	474.8	-23.6	-5.0
Sudan	574	609	427	362	375	264	370	360	400	375	411.6	635.4	-223.8	-35.2
Zaire	320	347	357	367	375	375	380	380	380	380	366.1	294.4	71.7	24.4
Brazil	275	301	239	226	325	196	198	170	165	151	224.6	414.4	-189.8	-45.8
Argentina	170	222	151	194	161	192	395	250	179	213	212.7	387.5	-174.8	-45.1
Others	3360	3491	3168	3181	3270	3481	3753	3851	4023	3981	3555.9	3775.8	-219.8	-5.8

Table 15. Crushing and food use as percentage of domestic groundnut utilization by the major consuming countries, 1980–89.

Regions	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	Average 1980s	Average 1970s	Change	Change (%)
Crushed														
India	80.63	79.82	81.09	80.05	80.68	80.88	80.38	80.43	80.35	80.33	80.46	80.29	0.17	0.22
China	50.59	51.49	51.98	51.52	55.02	54.99	54.98	55.39	54.95	54.59	53.55	49.58	3.98	8.02
USA	18.41	18.71	12.88	13.81	22.80	22.22	17.85	17.66	24.65	15.20	18.42	26.60	-8.18	-30.75
Indonesia	5.85	5.26	4.92	5.42	4.76	4.86	5.01	5.09	5.12	5.13	5.14	9.52	-4.38	-45.98
Senegal	49.81	65.83	61.21	45.82	33.04	48.55	59.38	65.39	60.86	68.21	55.81	74.16	-18.35	-24.75
Myanmar	74.01	73.94	80.04	80.08	80.06	80.00	79.96	79.96	80.00	80.00	78.80	69.00	9.81	14.21
Nigeria	38.49	38.55	38.38	38.41	39.62	39.28	44.34	21.32	21.49	19.44	33.93	76.82	-42.89	-55.83
Sudan	65.68	69.95	50.12	50.83	46.67	45.45	51.35	50.00	45.00	53.33	52.84	53.24	-0.40	-0.75
Zaire	33.44	34.58	34.45	34.60	34.40	34.40	33.95	33.95	33.95	33.95	34.17	35.20	-1.03	-2.93
Brazil	71.27	83.72	79.50	70.80	76.92	59.18	47.98	35.29	33.33	29.80	58.78	77.98	-19.20	-24.63
Argentina	86.47	90.54	74.83	63.40	80.12	73.96	88.61	72.00	63.69	67.14	76.08	84.60	-8.53	-10.08
Others	29.58	32.28	29.58	27.60	26.94	27.06	27.26	26.51	26.27	25.85	27.89	26.38	1.51	5.72
World	52.27	56.09	53.28	53.75	54.63	51.98	53.52	51.53	55.68	54.18	53.69	58.07	-4.38	-7.54
Food use														
India	6.46	6.72	6.30	6.66	6.43	6.34	6.55	6.52	6.55	6.56	6.51	7.34	-0.83	-11.30
China	38.15	38.81	39.22	38.88	36.98	37.00	36.65	36.93	36.63	36.39	37.57	37.41	0.16	0.42
USA	60.44	55.32	69.58	65.54	69.14	53.88	72.03	65.30	68.27	71.18	65.07	60.88	4.19	6.88
Indonesia	84.83	86.41	80.44	82.97	83.66	83.96	83.88	83.76	83.93	84.01	83.79	79.81	3.87	4.98
Senegal	19.50	14.68	14.82	30.06	49.11	30.94	26.37	18.60	23.69	17.89	24.57	9.18	15.39	167.72
Myanmar	21.11	21.10	14.97	15.04	14.99	15.00	15.07	15.03	14.87	14.96	16.21	26.00	-9.79	-37.64
Nigeria	41.51	41.59	41.67	41.62	41.51	42.66	40.00	69.08	67.05	69.44	49.61	18.72	30.90	165.10
Sudan	26.31	22.66	44.03	41.16	46.67	46.97	43.24	44.44	47.50	40.00	40.30	29.93	10.37	34.64
Zaire	57.81	59.65	59.66	59.67	59.73	59.73	60.26	60.26	60.26	60.26	59.73	60.28	-0.55	-0.91
Brazil	13.45	8.31	10.46	18.14	12.31	23.98	40.40	48.82	51.52	54.97	28.24	11.07	17.17	155.14
Argentina	7.06	5.41	18.54	28.87	9.32	8.85	4.30	12.00	16.76	14.08	12.52	9.47	3.05	32.17
Others	62.59	60.10	61.93	64.95	65.81	66.53	67.47	68.09	68.68	68.93	65.51	53.43	12.08	22.61
World	35.51	31.86	35.01	34.26	35.24	36.99	36.91	38.58	34.42	35.49	35.43	31.04	4.39	14.13

Domestic groundnut utilization for the top ten consuming countries is shown in Tables 14 and 15. Once again, China had the largest increase from the 1970s to the 1980s. India, China and USA accounted for approximately 64% of the world domestic utilization. India has not changed the amount crushed but has slightly decreased its food use. China has increased its crushing use with basically no change in food use.

Table 16. Percentage distribution of groundnut trade, 1980–89.

Regions	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	Average 1980s	Average 1970s	Change
Major exporters													
USA	19.96	25.92	28.40	33.60	35.55	34.65	23.50	21.59	26.99	31.01	28.05	32.88	-4.83
China	26.71	15.59	21.32	20.84	19.42	24.32	31.07	27.68	21.37	16.58	22.78	3.72	19.05
Argentina	6.48	6.36	10.20	12.06	10.67	13.63	13.27	11.57	9.86	13.02	10.86	3.71	7.15
Sudan	11.65	13.01	6.43	5.08	1.37	0.81	0.78	5.78	4.33	2.07	4.90	14.57	-9.67
Hong Kong	4.55	7.45	5.15	2.19	2.73	4.03	5.00	3.24	3.63	3.48	4.12	0.60	3.52
India	6.22	4.57	3.22	5.98	3.65	1.10	3.12	0.77	6.06	5.80	3.93	6.88	-2.96
Gambia	1.31	4.27	6.43	3.39	3.01	1.83	3.12	4.24	4.67	4.64	3.65	4.90	-1.24
Vietnam	0.61	1.79	3.68	3.29	3.19	3.30	3.12	3.08	3.46	3.32	2.90	1.28	1.63
Netherlands	1.84	2.28	1.10	2.09	2.01	2.20	3.20	4.39	4.76	4.56	2.89	1.38	1.52
South Africa	4.55	3.87	0.46	0.60	4.28	1.54	1.25	2.85	4.33	4.15	2.77	5.49	-2.72
Singapore	2.36	0.70	2.02	1.60	3.19	2.86	2.97	3.86	2.60	2.49	2.53	0.86	1.67
Others	13.75	14.20	11.58	9.27	10.94	9.74	9.60	10.95	7.96	8.87	10.62	23 72	-13.10
Major importers													
EEC													
UK	11.74	9.84	12.40	10.39	12.14	14.13	11.59	12.46	13.07	13.72	12.15	10.01	2.19
Netherlands	8.85	8.94	9.90	12.25	13.26	11.83	13.96	11.65	12.75	12.91	11.63	7.71	3.97
Germany	6.57	7.85	6.92	7.45	9.24	8.41	8.36	8.74	10.21	9.85	8.36	7.25	1.16
France	9.47	8.84	6.15	11.47	7.94	6.43	4.02	5.99	4.82	4.84	7.00	24.72	-17.86
Italy	4.73	6.68	2.88	4.02	2.89	2.70	2.52	2.51	2.78	2.74	3.45	9.15	-5.75
Subtotal	45.57	52.17	49.13	51.86	51.54	49.13	47.08	50.08	51.96	52.54	50.11	68.87	-18.79
Japan	8.76	7.67	10.38	11.57	10.08	10.00	8.99	10.03	10.13	10.49	9.81	8.49	1.30
Canada	8.24	7.49	8.37	8.92	8.50	8.02	8.44	5.50	5.72	5.65	7.48	7.80	-0.38
Singapore	3.16	2.17	3.85	3.53	5.32	5.95	5.91	8.90	7.35	7.26	5.34	1.68	3.77
CIS (formerly USSR)	5.61	6.32	5.77	6.57	7.38	4.76	4.42	4.05	4.90	4.04	5.38	3.79	1.52
Hong Kong	5.61	8.12	6.83	2.65	3.36	6.03	5.68	4.45	4.49	5.25	5.25	1.53	3.73
Indonesia	1.31	8.12	5.77	2.94	2.24	3.89	5.21	3.32	1.63	1.61	3.60	0.31	3.26
Others	21.74	7.94	9.90	11.96	11.58	12.22	14.27	13.67	13.81	13.16	13.03	7.52	5.58

The USA has decreased crushing use and increased food use. Many of the other countries had decreases in crushing and increases in food use.

The USA, China, and Argentina are the major world groundnut exporters (Table 16). Their share increased from approximately 40% during the 1970s to 62% during the 1980s. Sudan was a major exporter during the 1970s, but its importance declined significantly during the 1980s. The export market has become more concentrated in the 1980s as indicated by the decreased share accounted for by countries not in the top ten. In contrast, the import market is less concentrated. Countries outside the top ten increased their share of the import market. While the EEC's import share has declined, some countries within the EEC (UK, the Netherlands, and Germany) have increased their share.

Conclusions

Groundnuts are one of the principal oilseeds in the world. Even though groundnut has experienced significant production growth in the 1980s over the 1970s, rape seed (canola) has surpassed it in terms of world production in the early 1990s. Furthermore, sunflower seed is close behind. This change in world ranking may be attributable to the emergence of health concerns in the industrial countries. Rape seed and sunflower oil are known to possess the best oil properties for human consumption. Thus, groundnut oil properties need to be reexamined in light of the current health concerns. Also, groundnut oil is not as price competitive on the world market. This was seen in the decline of the African countries in the world groundnut oil export market and the EEC in the groundnut oil import market.

While world harvested area changed very little from the 1970s to the 1980s, there were definite regional and subregional shifts. Asia and, in particular, China increased their share significantly, while Africa's share decreased. A similar picture was seen for yield. Asia and China had the largest yield increases while Africa's yield declined overall from the 1970s to the 1980s despite a modest increase in West Africa.

Since the mid-1970s, edible groundnuts have increased in importance in both domestic consumption and export trade. The USA has been developing the edible market in the EEC, Canada, and Japan. This has helped other countries, particularly Argentina and China, in their exports. However, two key factors exist that may change the groundnut environment in the 1990s and beyond. One of the factors is aflatoxin. This factor is a key item in the edible trade as well as the domestic market. The USA, the EEC, and other developed countries are lowering the limits allowed for aflatoxin in edible groundnuts. Aflatoxin is a key problem for African countries wishing to enter the edible trade market on a large scale.

The second factor deals with GATT and individual country domestic policies. If a GATT agreement is reached, trading and production patterns could change for the 1990s and beyond. In conclusion, the world groundnut market is not static. It is a dynamic, ever-changing environment.

Additional Literature Consulted

Cummins, D.G., and **Jackson, C.R.** (eds.) 1982. World peanut production, utilization and research. Special Publication no. 16. Athens, Georgia, USA: Georgia Agricultural Experiment Station.

Jellema, B.M. 1972. Analysis of the world market for groundnuts and groundnut products. Ph.D. thesis, North Carolina State University, Raleigh, North Carolina, USA.

Lu, C.M. 1989. An analysis of the impact of current policy on the international peanut market. M.S. thesis, University of Georgia, Athens, Georgia, USA.

Woodroof, J.G. (ed.) 1983. Peanuts: production, processing, products. 3rd edn. Westport, Connecticut, USA: AVI Publishing Co.

Appendix 1. Means of the world groundnut production, utilization, exports, and imports in 1980s, by countries and regions.

Countries	Harvested area ('000 ha)	Yield (t ha^{-1})	Production ('000 t)	Utilization ('000 t) Total	Food use	Crushed	Other uses	Exports ('000 t)	Imports ('000 t)
Americas									
North America									
United States	602.2	2.78	1672.6	1361.9	883.5	253.1	225.3	326.5	19.1
Mexico	56.5	1.33	73.6	75.9	73.2	1.2	1.5	1.0	2.9
Canada	-[1]	-	0.3	86.5	86.5	0.0	0.0	0.0	86.2
Subtotal	658.7	2.65	1746.5	1524.3	1043.2	254.3	226.8	327.5	108.2
South America									
Argentina	168.0	2.01	338.2	212.7	24.7	164.2	23.8	126.4	0.0
Brazil	160.3	1.46	228.9	224.6	54.6	141.9	28.1	13.2	9.4
Paraguay	34.2	1.06	36.2	22.8	1.1	19.4	2.3	13.4	0.0
Dominican Republic	22.8	0.86	19.7	19.7	0.5	16.7	2.5	0.0	0.0
Bolivia	13.6	1.10	15.2	15.3	12.9	2.0	0.4	0.0	0.2
Venezuela	6.5	1.63	10.1	10.2	6.3	3.0	0.9	0.0	0.1
Ecuador	9.2	0.92	8.2	8.2	5.7	1.8	0.7	0.0	0.0
Colombia	3.5	1.54	5.4	5.4	4.5	0.9	0.0	0.0	0.0
Uruguay	2.1	0.55	1.2	1.2	1.2	0.0	0.0	0.0	0.0
Trinidad and Tobago	0.0	0.0	0.0	3.8	3.8	0.0	0.0	0.0	3.8
Subtotal	420.2	1.59	663.1	523.9	115.3	349.9	58.7	153.0	13.5
Total	1078.9	2.24	2409.6	2048.2	1158.5	604.2	285.5	480.5	121.7
Africa									
East Africa									
Sudan	681.9	0.69	468.7	411.6	158.5	224.6	28.5	57.1	0.0
Uganda	123.8	0.84	104.3	104.3	65.4	34.3	4.6	0.0	0.0
Tanzania	97.1	0.61	59.1	59.1	30.1	26.0	3.0	0.0	0.0
Burundi	38.5	1.30	49.8	49.8	41.7	5.4	2.7	0.0	0.0
Subtotal	941.3	0.73	681.9	624.8	295.7	290.3	38.8	57.1	0.0
Southern Africa									
South Africa	217.3	0.86	179.2	160.2	53.3	92.3	14.6	32.3	10.0
Malawi	177.3	0.48	91.9	79.8	44.1	13.6	22.1	11.8	0.0
Zimbabwe	195.7	0.38	74.9	74.6	65.0	7.1	2.5	1.9	0.0
Mozambique	152.0	0.48	72.5	70.8	44.5	23.3	3.0	1.7	0.0
Madagascar	33.1	0.97	32.2	32.2	17.5	13.7	1.0	0.0	0.0
Zambia	46.8	0.48	21.8	17.4	13.5	2.6	1.3	4.3	0.0
Subtotal	822.2	0.57	472.5	435.0	237.9	152.6	44.5	52.0	10.0
West Africa									
Senegal	903.0	0.83	740.0	746.6	173.3	429.7	143.6	3.0	11.6
Nigeria	625.9	0.72	442.0	451.1	219.2	156.1	75.8	0.3	10.4
Zaire	517.2	0.71	366.1	366.1	218.8	125.1	22.2	0.0	0.0
C. African Rep.	123.3	1.08	133.1	133.1	53.4	73.1	6.6	0.0	0.0
Cameroon	318.9	0.38	122.2	121.3	86.1	28.8	6.4	0.9	0.0
Gambia	98.9	1.17	115.3	72.3	10.2	54.5	7.6	42.5	0.0
Burkina Faso	182.0	0.61	114.8	114.8	16.8	87.4	10.6	0.0	0.0
Côte d'Ivoire	111.2	0.93	103.9	105.9	91.5	7.3	7.1	0.0	2.0

Continued

Appendix 1. *Continued*

Countries	Harvested area ('000 ha)	Yield (t ha-1)	Production ('000 t)	Utilization ('000 t) Total	Food use	Crushed	Other uses	Exports ('000 t)	Imports ('000 t)
Guinea	129.7	0.66	85.0	85.0	50.0	31.0	4.0	0.0	0.0
Mali	100.4	0.84	84.4	80.7	14.6	59.0	7.1	3.7	0.0
Chad	107.1	0.70	75.0	75.0	46.0	25.0	4.0	0.0	0.0
Niger	129.8	0.54	71.5	71.5	49.5	19.0	3.0	0.0	0.0
Benin	78.5	0.87	68.2	68.2	40.1	23.8	4.3	0.0	0.0
Ghana	91.4	0.57	52.3	52.3	49.8	0.0	2.5	0.0	0.0
Togo	45.0	0.72	32.5	29.9	17.3	10.6	2.0	2.6	0.0
Guinea-Bissau	80.5	0.36	28.7	19.1	7.1	9.8	2.2	9.6	0.0
Subtotal	3642.8	0.72	2635.0	2592.9	1143.7	1140.2	309.0	62.6	24.0
Total	5406.3	0.70	3789.4	3652.7	1677.3	1583.1	392.3	171.7	34.0
Asia									
East Asia									
China	2731.2	1.81	4981.7	4716.6	1763.3	2542.4	410.9	265.2	0.1
Taiwan	49.3	1.68	82.3	82.9	60.4	12.8	9.7	0.3	0.9
Japan	26.8	1.78	47.6	160.9	141.5	1.9	17.5	0.0	113.7
Korea, Republic	13.5	2.60	35.3	44.4	43.5	0.0	0.9	0.0	9.9
Hong Kong	0.0	0.00	0.0	13.1	13.1	0.0	0.0	48.0	61.1
Subtotal	2820.8	1.81	5146.9	5017.9	2021.8	2557.1	439.0	313.5	185.7
Southeast Asia									
Indonesia	528.3	1.48	780.2	819.1	686.2	42.1	90.8	1.6	41.5
Myanmar	577.2	0.95	549.8	549.8	88.5	433.9	27.4	0.0	0.0
Thailand	118.2	1.33	157.5	148.9	99.5	32.9	16.5	10.1	0.0
Vietnam	171.0	0.91	155.9	122.1	32.9	70.9	18.3	33.8	0.0
Philippines	48.5	0.87	42.3	52.9	42.9	0.0	10.0	0.0	10.6
Bangladesh	29.4	1.15	34.1	34.1	5.4	26.8	1.9	0.0	0.0
Malaysia	6.0	2.33	14.0	31.2	18.9	9.3	3.0	0.0	17.2
Singapore	0.0	0.00	0.0	33.9	33.2	0.0	0.7	29.4	63.3
Subtotal	1478.6	1.17	1733.8	1792.0	1007.5	615.9	168.6	74.9	132.6
Southwest Asia									
India	7362.8	0.87	6432.7	6407.0	417.8	5153.0	836.2	45.7	0.0
Pakistan	62.9	1.14	71.8	71.8	64.9	0.0	6.9	0.0	0.0
Subtotal	7425.7	0.87	6504.5	6478.8	482.7	5153.0	843.1	45.7	0.0
Total	11725.1	1.14	13385.2	13288.7	3512.0	8326.0	1450.7	434.1	318.3
Near East[2]									
Turkey	25.0	2.36	59.5	53.4	34.6	16.6	2.2	6.0	0.0
Morocco	27.9	1.42	40.2	39.7	38.2	0.0	1.5	0.0	0.0
Egypt	13.5	2.52	34.0	27.0	26.3	0.0	0.7	7.0	0.0
Israel	5.2	4.65	24.1	12.5	10.7	0.0	1.8	11.6	0.0
Syria	9.9	1.97	19.5	18.4	16.9	0.0	1.5	1.1	0.0
Jordan	0.0	0.00	0.0	3.1	3.1	0.0	0.0	0.0	3.1
Total	81.5	2.17	177.3	154.1	129.8	16.6	7.7	25.7	3.1
Europe									
EEC									
Spain	1.8	2.85	4.8	32.9	31.2	0.0	1.7	0.0	28.1
Italy	0.7	1.29	0.9	40.4	24.0	16.4	0.0	0.0	39.5

Continued

Appendix 1. *Continued*

Countries	Harvested area ('000 ha)	Yield (t ha⁻¹)	Production ('000 t)	Utilization ('000 t) Total	Food use	Crushed	Other uses	Exports ('000 t)	Imports ('000 t)
Belgium/ Luxembourg	0.0	0.00	0.0	6.7	3.8	2.9	0.0	0.3	7.0
France	0.0	0.00	0.0	78.2	33.8	44.4	0.0	1.5	79.7
Netherlands	0.0	0.00	0.0	100.9	96.2	2.2	2.5	33.7	135.6
Portugal	0.0	0.00	0.0	21.0	2.5	18.5	0.0	0.3	20.9
United Kingdom	0.0	0.00	0.0	137.1	137.1	0.0	0.0	4.1	141.7
West Germany	0.0	0.00	0.0	89.4	87.1	0.0	2.3	8.0	97.6
Subtotal	2.5	2.28	5.7	506.6	415.7	84.4	6.5	47.9	550.1
East Europe									
CIS (formerly USSR)	1.0	1.70	1.7	63.3	63.3	0.0	0.0	0.0	61.6
Czechoslovakia	0.0	0.00	0.0	7.7	0.0	7.7	0.0	0.0	7.7
Hungary	0.0	0.00	0.0	2.2	2.2	0.0	0.0	0.0	2.2
Yugoslavia	0.0	0.00	0.0	6.0	6.0	0.0	0.0	0.0	6.0
Subtotal	1.0	1.70	1.7	79.2	71.5	7.7	0.0	0.0	77.5
West Europe									
Austria	0.0	0.00	0.0	3.6	3.6	0.0	0.0	0.0	3.6
Norway	0.0	0.00	0.0	3.1	3.1	0.0	0.0	0.0	3.1
Sweden	0.0	0.00	0.0	3.3	3.3	0.0	0.0	0.0	3.3
Switzerland	0.0	0.00	0.0	31.1	4.1	27.0	0.0	0.0	31.1
Subtotal	0.0	0.00	0.0	41.1	14.1	27.0	0.0	0.0	41.1
Total	3.5	2.24	7.4	626.9	501.3	119.1	6.5	47.9	668.7
Oceania									
Australia	30.6	1.36	40.9	43.3	36.2	6.0	1.1	4.3	5.8
New Zealand	0.0	0.00	0.0	10.2	10.2	0.0	0.0	0.0	10.2
Total	30.6	1.36	40.9	53.5	46.4	6.0	1.1	4.3	16.0
World	19325.9	1.08	19809.8	19823.0	10655.0	7024.2	2143.8	1164.2	

1. Data not available.
2. Near East includes Mediterranean countries.

The Performance of African Groundnut Council Countries in Groundnut Production and Trade

O. Badiane[1]

Abstract

*Traditional agricultural exports in many African countries have experienced serious difficulties over the last two decades. A long-term decline in external demand and other factors related to international markets are the most commonly cited reasons for these difficulties. The ongoing debate on regional economic cooperation seems to suggest the hope that regional markets could, at least in part, act as a substitute for international markets. Using the example of groundnuts (*Arachis hypogaea*), the present paper investigates the role of domestic and external factors in the decline of traditional exports, and the role regional markets could play in their future development. Its findings indicate that African groundnut exports have suffered more from domestic policies than from external demand factors. The findings also reveal that African exporters rarely exported to regional markets, even though demand there for vegetable oils grew at a rate two and half times higher than in global markets.*

Based on the high elasticity of the share of groundnuts in regional demand for vegetable oils imports, with respect to the own price of groundnut oil, and on the responsiveness of groundnut oil export supply by African countries to country real exchange rates, the study concludes that (re)capturing regional markets would produce the same conditions as would reversing the declining performance of African exporters on overseas markets. In this sense, regional and foreign export markets are not substitutes.

Résumé

La production et le commerce de l'arachide dans les pays membres du Conseil africain de l'arachide: *Les exportations agricoles traditionnelles de bien des pays africains ont subi de graves difficultés depuis deux décennies. Une baisse à long terme de la demande externe et d'autres facteurs relatifs aux marchés internationaux sont les raisons citées le plus fréquemment de ces difficultés. Le débat engagé sur la coopération économique régionale semble indiquer l'espoir que les marchés régionaux pourraient, au moins en partie, se substituer aux marchés internationaux. Prenant l'exemple de l'arachide (*Arachis hypogaea*), cette communication étudie le rôle des facteurs intérieurs et externes des exportations traditionnelles et le rôle que les marchés régionaux pourraient jouer pour leur développement à l'avenir. Ses conclusions indiquent que les exportations africaines d'arachide ont été affectées davantage par les politiques intérieures que par des facteurs de la demande externe. Les conclusions révèlent aussi que les pays africains exportaient rarement vers des marchés régionaux, même si la demande de ces marchés pour des huiles végétales ait augmenté à un taux deux fois et demie plus élevé que sur les marchés mondiaux.*

Sur la base de la forte élasticité de la part de l'arachide dans la demande régionale d'importation de l'huile végétale, en ce qui concerne le prix intrinsèque de l'huile d'arachide et de la réponse

---

1. Economist, International Food Policy Research Institute (IFPRI), 1776 Massachusetts Avenue, N.W., Washington, D.C. 20036-1998, USA.

Member countries of the African Groundnut Council (AGC) are Gambia, Mali, Niger, Nigeria, Senegal, and Sudan. This paper has been completed as part of the project on the Regional Integration of Agricultural Markets in Africa supported by the Swiss Development Corporation. It draws on a joint IFPRI/AGC study under the same project.

Badiane, O. 1992. The performance of African Groundnut Council countries in groundnut production and trade. Pages 33–51 *in* Groundnut – a global perspective: proceedings of an international workshop, 25–29 Nov 1991, ICRISAT Center, India (Nigam, S.N., ed.). Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

des pays africains à l'offre de l'huile d'arachide à l'exportation en tenant compte des taux des changes réels des pays, l'étude conclut que capturer (de nouveau) les marchés régionaux produirait les mêmes conditions que si les exportateurs africains avaient renversé leur tendance à la baisse sur les marchés d'outre-mer. Dans ce sens, les marchés régionaux et étrangers d'exportations ne sont pas des substituts.

From independence to the beginning of the major Sahelian drought in 1969, a central feature of the overall development experience in the African Groundnut Council (AGC) countries has been the overriding role played by the export-oriented groundnut sector in these economies. Well before the countries became independent, groundnut production, marketing, and trade served as major sources of employment, income, and foreign exchange. The groundnut sector provided the basis for agroindustrial development, and contributed significantly to the commercialization, monetarization, and integration of the national rural sectors.

Until the mid-1970s, groundnut production, processing, and trade contributed between 15% (Senegal) and 40% (Gambia) of gross domestic production in AGC countries. With the exception of Nigeria and Sudan, groundnut exports provided between 40% to 90% of export revenues of AGC countries during the 1960s and the early 1970s. The share of the labor force employed in the groundnut sector varied between 30% and 80% across individual AGC countries other than Nigeria (Kinteh and Badiane 1990).

The contribution of the groundnut sector to national economies changed dramatically after the middle of the 1970s, as shown by Figures 1a to 1d. The figures present the evolution of income terms of trade for the various countries, calculated as groundnut export revenues deflated by the world manufacturing unit value. After a period of relative stability during the 1960s, the income terms of trade fell continuously over the next one and a half decades. Toward the end of the 1980s the figures were about 50% to 80% below their level in the 1960s. The trend depicted in Figure 1 may have had a similar consequence across AGC countries, namely a strong pessimism about long-term contribution of the external sector to growth in the groundnut economy. Its reasons are, however, still the subject of a great deal of speculation.

This explains the objective of the present paper, which is first, to test the validity of the frequent argument that external demand stagnation is responsible for the declining contribution of the groundnut sector to the countries' economies, and second, to evaluate the possible role played by internal factors therein, particularly of the domestic macroeconomic and trade environments.

Production and Trade Performance in AGC Countries

Production of groundnut and other oilseeds

Despite deteriorating production performance over the last three decades, groundnut remains the most important source of vegetable oils and fats in Africa (Table 1). This reveals Africa's low participation in the rapid structural changes in the global vegetable oils and fats sector over the last three decades, despite its successes in the development of other competing crops.

Soybean (*Glycine max*) production grew by an annual rate of 8.26% during 1961–1988 to reach an average of 382 441 t annually in 1982–87. Although this output level is relatively negligible in global terms, the annual production growth rate, and the component of it that derived from productivity gains, surpass the corresponding figures for the world average. Similarly, the same parameters for sunflower (*Helianthus annuus*) production in Africa exceed their corresponding world levels. The figures for sesame (*Sesamum indicum*) production in Africa show the levels to be comparable to world production levels. The potential of sesame, however, to serve as the second crop in a sequential cropping system (as in some mono-modal rainfall regions), as well as its versatility in the local diet, render it a promising oilseed crop.

Cotton (*Gossypium* spp) seed, palm oil (*Elacis* spp), and palm kernel production growth rates in Africa are still below world patterns. These commodities, however, still do better than groundnuts, which display a negative growth rate. Cotton competes with groundnuts for land and farm labor. Given the prospects in the fiber market, the relatively adequate institutional arrangements for cotton production, and the relatively drought-tolerant character of the crop, cotton production is likely to be a competitive force to reckon with for the groundnut sector.

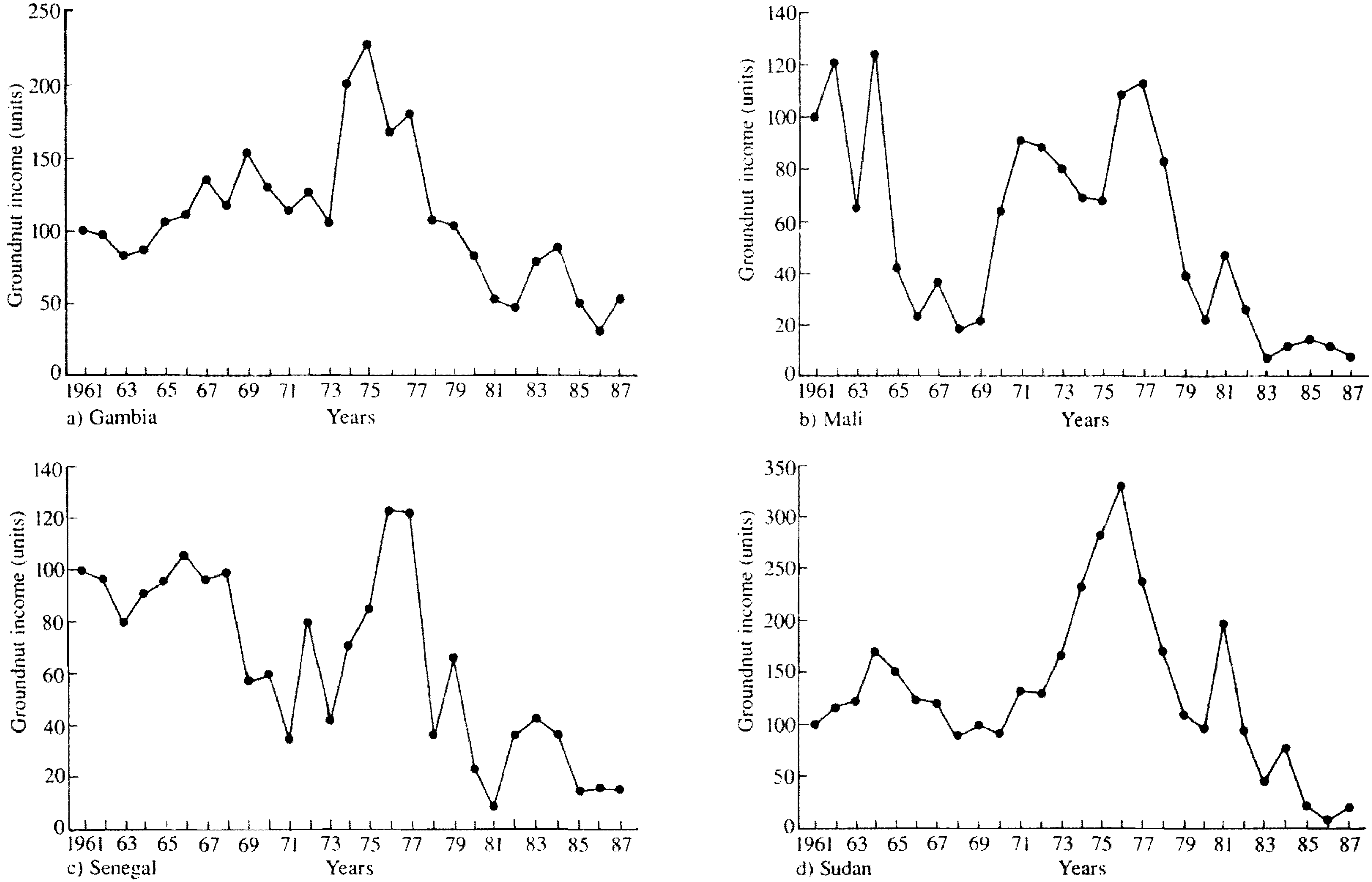


Figure 1. Groundnut income terms of trade (1961 = 100 units). *Groundnut export revenue deflated by manufacturing unit value (MUV); Nigeria became a net importer in the early 1970s.*

Table 1. Trends in the evolution of African production of major oilseeds and oleaginous fruits from 1961–1988: area harvested, production, and yields in-shell.

Commodity	Production: Average 1982–87 ('000 t)	Production: Annual growth rate 1961–1988 (%)	Area: Average 1982–87 ('000 ha)	Area: Annual growth rate 1961–1988 (%)	Yield: Average 1982–87 (kg)	Yield: Annual growth rate 1961–1988 (%)
Soybeans	38.24	8.25	388.24	3.32	986	4.90
Groundnuts	4146.94	-1.11	5585.72	-0.77	744	-0.40
Castor beans	37.59	-2.58	74.52	-2.22	504	-0.36
Sunflower seed	432.16	7.24	600.83	5.22	715	2.02
Sesame seed	483.09	1.04	1676.83	1.98	288	-0.94
Linseed	63.16	-0.75	101.05	-1.73	635	0.98
Coconuts	1677.04	1.09	-[1]	-	-	-
Copra	210.20	1.72	-	-	-	-
Palm kernels	662.08	-0.76	-	-	-	-
Palm oil	1441.71	1.20	-	-	-	-
Cotton seed	2183.76	0.74	-	-	-	-

1. Data were not available.
Source: IFPRI Database.

Both palm oil and palm kernel production have performed better than groundnuts. Given overall slow income growth rates in Africa, and the competitive price of palm oil coupled with the prospects of rapid adoption of existing technologies in oil palm production, the competitive market pressures from both palm and kernel oils are likely to intensify, at least in the medium term, as evident from the strong import growth rates of these oils discussed elsewhere in this paper.

Table 2 summarizes the evolution of other oilseeds and oleaginous fruits production in individual AGC countries since 1961. Except for Gambia, the relative performance of groundnut production, depicted at the Africa regional level, is also apparent in all AGC countries. Cottonseed production in Mali and Senegal seems to be emerging rapidly with an average output in 1982–87 of 106 333 t in Mali and 20 666 t in Senegal, with corresponding impressive annual growth rates of 10.46% and 17.64%. Sesame production has also increased in Niger, Nigeria, and Sudan. This output expansion is invariably a result of area expansion, particularly in Sudan. Palm oil production shows some strong signs in Senegal with an annual growth rate of 2.02%, ranking second to cotton seed in production growth during the period 1961–1988. In terms of AGC shares in total African production of major oilseeds and oleaginous fruits products, sesame seed, palm oil, and palm kernel are the most important crops. Sesame seed accounts for 46%, palm oil for 51%, and palm kernel for 52% of African production.

Table 3 presents the evolution of African groundnut production in terms of average output, cultivated area, and yields for the period 1982–87. Groundnut production in Africa averaged about 4 million t of groundnuts in shell. Since 1961, production has steadily declined by an annual growth rate of 1.17%, over 65% of which is explained by reduction in cultivated area.

The West African subregional situation contrasts poorly even with the overall African picture. Production of the West African exporters and Sudan averaged about 2.4 million t per year during 1982–87, slightly below 60% of total African production for that period. Since 1961, the share of West African producers, again including Sudan, declined at an annual rate of 2%, 84% of which is accounted for by reduction in cultivated area.

Production in the six non-AGC West African exporters grew by 2.11% annually during 1961–1988, contrasting sharply with a growth rate of -2.6% per annum in AGC countries. With the exception of Guinea-Bissau, production expanded in all other non-AGC countries led by Côte d'Ivoire with the highest growth rate both in terms of expansion in area har-

Table 2. Evolution of production of other major oilseeds and oleaginous fruits in AGC countries: area harvested, production, and yields from 1961–1988.

Aggregation	Commodity	Production: Average 1982–87 ('000 t)	Production: Average share of Africa 1982–87 (%)	Production: Annual growth rate 1961–1988 (%)	Area: Average 1982–87 ('000 ha)	Area: Annual growth rate 1961–1988 (%)	Yield: Average 1982–87 (kg)	Yield: Annual growth rate 1961–1988 (%)
Gambia	Palm kernels	2.00	0.30	0.14	-[1]	-	-	-
	Cotton seed	1.12	0.05	-1.19	-	-	-	-
Mali	Cotton seed	106.33	4.87	10.46	-	-	-	-
Niger	Sesame seed	0.20	0.04	7.15	0.66	6.40	310	0.67
	Cotton seed	1.90	0.09	-3.44	-	-	-	-
Nigeria	Soybeans	58.00	15.17	-0.09	205.00	0.80	280	-0.90
	Sesame seed	725.00	15.53	1.36	245.83	0.40	310	0.90
	Coconuts	98.83	5.89	0.73	-	-	-	-
	Copra	11.77	5.60	1.31	-	-	-	-
	Palm kernels	334.83	50.57	-0.31	-	-	-	-
	Palm oil	725.00	50.29	0.56	-	-	-	-
	Cotton seed	37.83	1.73	-3.36	-	-	-	-
Senegal	Soybeans	0.17	0.04	-	0.16	-	1040	-
	Coconuts	4.53	0.27	-0.82	-	-	-	-
	Palm kernels	5.63	0.85	-0.03	-	-	-	-
	Palm oil	6.00	0.42	2.02	-	-	-	-
	Cotton seed	20.67	0.95	17.64	-	-	-	-
Sudan	Castor bean	5.22	18.88	-3.05	10.42	0.80	500	-3.90
	Sunflower seed	-	-	-	-	-	-	-
	Sesame seed	184.50	38.19	0.58	911.61	3.60	200	-3.00
	Cotton seed	342.50	15.68	-0.12	-	-	-	-

1. Data were not available.
Source: IFPRI Database.

vested and improvement in productivity. Area reduction has been the major force behind the fall in production in AGC countries.

Trade in groundnuts and other oilseeds

Groundnut and oil palm are by far the most important oilseeds grown and exported by African countries. In addition, soybean and sunflower products also play a large role in African oilseed imports, and their demand has been expanding rapidly over the last three decades.

The figures in Table 4 show the still strong, albeit dwindling, position of African exporters on international markets for groundnut oil and palm kernels. During the 1982–87 period, 14% of the nearly 500 000 t of world groundnut oil exports originated from Africa, as did virtually all palm kernel exports. African oilseed exports, on the other hand, display a falling trend in all product categories with the exception of palm kernels. AGC shares in African exports of groundnut and oil palm products have been substantial, ranging from 32% to over 90% for groundnut products and from 31% to 43% for palm kernel products. The largest AGC exporters are Nigeria (for all palm kernel products), Senegal (for groundnut oil and cake), and Sudan (for nonprocessed groundnuts).

AGC and African exports of nonprocessed oilseeds and fruits have also been declining for all products, except for in-shell groundnut in Niger. The reduction in groundnut oil exports has been considerable in the case of Niger and Nigeria. The only country with a strong positive export growth rate for that

Table 3. Evolution of African groundnut production by selected countries from 1961-1988: area harvested, production, and yields in-shell.

Aggregation	Production: Average 1982–87 ('000 t)	Production: Average share of Africa 1982–87 (%)	Area: Average 1982–87 ('000 ha)	Area: Annual growth rate 1961–1988 (%)	Yield: Average 1982–87 (kg)	Yield: Annual growth rate 1961–1988 (%)
Africa	4146.94	100	5585.72	-0.77	744	-0.40
Gambia	105.83	2.55	86.25	-0.52	1308	-0.19
Mali	67.50	1.63	104.58	-2.26	721	0.05
Niger	47.26	1.14	141.93	-4.47	382	-2.56
Nigeria	662.00	15.96	599.50	-5.83	1007	0.36
Senegal	714.15	17.22	888.39	-0.94	882	-0.20
Sudan	402.17	9.70	634.65	3.73	639	-1.71
Total AGC Countries	1998.91	48.20	2455.31	-2.29	831	-0.32
Benin	57.53	1.39	79.06	0.24	650	2.64
Guinea	76.20	1.84	132.37	1.09	588	-0.23
Guinea-Bissau	28.00	0.68	68.32	-1.86	448	-0.70
Burkina Faso	122.29	2.95	179.58	2.02	589	0.55
Côte d'Ivoire	106.17	2.56	107.83	3.48	938	2.70
Togo	25.71	0.62	51.10	1.56	496	0.23
Total of Non-AGC West African Exporters	415.90	10.03	618.26	1.17	633	0.95
Total AGC Non-AGC West African Exporters	2414.81	58.23	3073.56	-1.75	789	-0.34

Source: IFPRI Database.

product category was Mali, which started from very low levels. It is also interesting to note the rapid expansion of palm product exports by the group of AGC countries, compared with a mere 1% growth for groundnut cake, or even a 3.6% decline for groundnut oil.

The patterns of oilseed imports to African and AGC countries are presented in Table 5. Except for soybeans, African imports of oilseed products consist mainly of oil. In 1982–87 the main vegetable oil imported by African countries was palm oil, followed by soybean oil. Groundnut oil imports were relatively small and were primarily directed to West African countries. Overall, oil imports to African countries have been expanding rapidly throughout the study period, with growth rates ranging from 12% to 18%. For the group of African countries groundnut oil imports have been increasing by slightly more than 1%. For the three main West African importers, however, the growth rate of groundnut oil imports has exceeded 10%.

Nigeria is the largest importer of vegetable oils in West Africa, with shares well over 90% for groundnut, soybean, and palm oil. While Nigeria still shows strong preference for groundnut oil, demand in the other two importing countries, Côte d'Ivoire and Ghana, has shifted relatively to soybean and palm oil.

The last three columns of Table 6 display the sharp decline in the role of the AGC in the world groundnut economy over the last two decades. Groundnut oil exports from member countries fell on average by 3.6% annually between the early 1960s and the late 1970s. The growth rates of Nigeria and Senegal, initially the two largest exporters, were -15% and -2%, respectively. Nigeria changed from being largest exporter among AGC countries, with a

Table 4. Evolution of African and AGC exports of groundnuts and oil palm products.

	Oilseeds and Fruits			Oil			Cake		
	Average 1982–87 ('000 t)	Average share 1982–87 (%)	Annual growth rate 1961–1987 (%)	Average 1982–87 ('000 t)	Average share 1982–87 (%)	Annual growth rate 1961–1987 (%)	Average 1982–87 ('000 t)	Average share 1982–87 (%)	Annual growth rate 1961–1987 (%)
Africa									
Groundnuts in shell	5.48	100	-11.1	-[1]	-	-	-	-	-
Groundnuts shelled	102.30	100	-11.1	-	-	-	-	-	-
Groundnut	-	-	-	141.70	100	-3.1	221.32	100	-3.2
Palm kernels	108.73	100	-11.1	56.20	100	-0.1	92.67	100	2.5
Palm	-	-	-	103.33	100	-4.9	-	-	-
Gambia									
Groundnuts in shell	-	-	-	-	-	-	-	-	-
Groundnuts shelled	259.39	25.5	-2.8	-	-	-	-	-	-
Groundnut	-	-	-	7.79	5.50	0.4	10.68	4.83	2.3
Palm kernels	-	0.05	-6.7[2a]	-	-	-	-	-	-
Mali									
Groundnuts in shell	-	-	-	-	-	-	-	-	-
Groundnuts shelled	1.78	1.64	-15.0	-	-	-	-	-	-
Groundnut	-	-	-	1.63	1.15	11.8[i]	6.11	2.76	7.2
Niger									
Groundnuts in shell	0.02	0.37	1.9	-	-	-	-	-	-
Groundnuts shelled	0.07	0.07	-40.2[b]	-	-	-	-	-	-
Groundnut	-	-	-	-	-	-	0.83	0.38	-9.9
Nigeria									
Groundnuts in shell	0.52	9.57	-45.2[c]	-	-	-	-	-	-
Groundnuts shelled	-	-	-	-	-	-	-	-	-
Groundnut	-	-	-	0.0	0.00	-14.8[g]	0.07	0.03	-33.1[f]
Palm kernels	5.65	51.93	-8.4	17.45	31.05	7.1	38.23	30.47	11.9
Senegal									
Groundnuts in shell	0.02	0.41	-26.6[d]	-	-	-	-	-	-
Groundnuts shelled	7.59	7.43	-20.3	-	-	-	-	-	-
Groundnut	-	-	-	111.16	78.44	-2.1	134.98	60.98	-2.4
Palm kernels	0.18	0.17	-31.7[c]	-	-	-	1.34	1.45	2.7[h]

Continued.

Table 4. Evolution of African and AGC exports of groundnuts and oil palm products. *Continued*

	Oilseeds and Fruits			Oil			Cake		
	Average 1982–87 ('000 t)	Average share 1982–87 (%)	Annual growth rate 1961–1987 (%)	Average 1982–87 ('000 t)	Average share 1982–87 (%)	Annual growth rate 1961–1987 (%)	Average 1982–87 ('000 t)	Average share 1982–87 (%)	Annual growth rate 1961–1987 (%)
Sudan									
Groundnuts in shell	1.19	21.71	-9.9[f]	-	-	-	-	-	-
Groundnuts shelled	2.41	35.59	-8.9	-	-	-	-	-	-
Groundnut	-	-	-	7.39	5.22	-0.17[j]	56.8	25.65	1.6
AGC									
Groundnuts in shell	1.21	32.06	-9.9[b]	-	-	-	-	-	-
Groundnuts shelled	29.47	70.23	-14.8	-	-	-	-	-	-
Groundnut	-	-	-	127.98	90.31	-3.6	209.44	94.64	1.0
Palm kernels	56.70	52.15	-8.5	17.46	31.06	7.1	39.58	42.71	11.7[c]

1. Data not available.
2. a = 1961-1982; b = 1961-1986; c = 1961-1986; d = 1966-1984; e = 1961-1985; f = 1961-1975; g = 1961-1983; h = 1963-1986; i = 1966-1987; j = 1973-1987.
Source: IFPRI Database.

share of 26% in world exports, to being a net importer by the end of the 1970s. At the same time, competitors from Asia and South America were able to increase exports by nearly 400%, raising their combined share from slightly over 10% in 1962–67 to 50% of world exports of groundnut products in 1986–88. As a result, AGC's export share fell from over 60% to a low of 20% during the same period. Whereas market shares were lost mainly to South American exporters in the early years, competition in the later period came mainly from Asia.

The reduction in groundnut exports is paralleled by a marked decrease in groundnut production in all six AGC countries except Sudan, as can be seen from the first two columns of Table 6. The decline has been substantial in Niger and Nigeria, with annual growth rates of -7% and -5%, respectively, over the study period. Aggregate production in all AGC countries decreased at a yearly rate of 2.61%, compared with a growth of 1.24% for the world and 2.46% for Asia. The poor performance is also reflected in the evolution of groundnut yields. While they increased in both Asia and South America, they fell in AGC countries by 0.32% a year over the last three decades, as compared with a world average growth rate of 1.19%.

The dramatic changes previously described for AGC exports occurred despite the relative stability of world demand for groundnut products during the same period. Together with the impressive expansion of Asian and South American trade shares, this seems to contradict sharply with the argument of an external demand constraint. The attempt is made, therefore, in the next section to isolate the contribution of changes in international demand and of domestic macroeconomic policies and trade strategies to the observed decline in AGC trade.

The Role of External Demand and Domestic Policies

A simple model of supply and demand for groundnut exports of the type developed in Goldstein and Khan (1978) is used to estimate the effects of changes in external demand and domestic factors on AGC countries' export performance. The demand for a single AGC country's exports is expressed as a function of that country's supply price, the average price of competing exports, and of the state of demand on world

Table 5. Evolution of African imports of major oilseeds and oleaginous fruit products by selected countries for the period 1961–1987.

	Oilseeds and Fruits			Oil			Cake		
	Average 1982–87 ('000 t)	Average share 1982–87 (%)	Annual growth rate 1961–1987 (%)	Average 1982–87 ('000 t)	Average share 1982–87 (%)	Annual growth rate 1961–1987 (%)	Average 1982–87 ('000 t)	Average share 1982–87 (%)	Annual growth rate 1961–1987 (%)
Africa									
Soybeans	55.30	100	13.59	388.86	100	8.64	692.50	100	37.22
Groundnuts	-[1]	-	-	21.80	100	1.35	4.40	100	-3.65
Groundnuts in shell	0.60	100	-10.35	-	-	-	-	-	-
Groundnuts shelled	26.77	100	1.98	-	-	-	-	-	-
Palm	-	-	-	703.23	100	18.84	-	-	-
Palm kernels	0.02	100	-27.87	42.58	100	12.56	-	-	-
Sunflower seeds	22.44	100	21.35	355.42	100	12.17	3.00	100	12.85
Ghana									
Soybeans	-	-	-	3.27	0.84	10.68	-	-	-
Groundnuts shelled	-	-	-	0.03	0.16	-15.22	-	-	-
Palm	-	-	-	4.30	0.61	13.61	-	-	-
Côte d'Ivoire									
Soybeans	-	-	-	0.58	0.15	5.20[2a]	-	-	-
Groundnuts shelled	-	-	-	0.12	0.55	-9.00	0.21	4.80	-21.65[c]
Nigeria									
Soybeans	-	-	-	23.03	5.92	-2.05[b]	17.50	2.58	-23.75[1]
Groundnuts	-	-	-	9.10	41.72	35.48[c]	-	-	-
Palm	-	-	-	136.83	19.45	50.89	-	-	-
Total of 6 countries									
Soybeans	-	-	-	26.89	6.92	18.84	17.50	2.53	23.75
Groundnuts	-	-	-	9.25	42.43	10.21	0.21	4.80	21.65[c]
Palm	-	-	-	141.13	20.07	21.50	-	-	-
Palm kernels	-	-	-	-	-	-	-	-	-

1. Imports of oilseeds and fruits to Ghana, Côte d'Ivoire and Nigeria were negligible during this period.
2. The estimation periods differ for a = 1963-1987; b = 1975-1987; c = 1963-1987; d = 1977-1987; e = 1966-1987; f = 1978-1987.

Table 6. Trade and production performance by AGC countries.

Country	Production growth rate (%)	Yield growth rate (%)	Share of groundnut exports in oil equivalent (%)		
			1961–65	1971–75	1986–88
Gambia	-0.71	-0.19	0.02	0.04	0.02
Mali	-2.21	0.05	0.02	0.04	0.01
Niger	-7.03	-2.56	0.04	0.05	0.00
Nigeria	-5.47	0.36	0.26	0.13	0.00
Senegal	-1.14	-0.20	0.23	0.15	0.14
Sudan	2.02	-1.71	0.05	0.07	0.03
South America	-1.85	1.43	0.05	0.16	0.18
Asia	2.46	1.78	0.08	0.09	0.32
AGC	-2.61	-0.32	0.62	0.48	0.20
World	1.24	1.19	1.00	1.00	1.00

Source: Production and trade data are from FAO yearbooks, various issues.

markets. That is,

$$EXPDEMj = f(PEXPj/PWRLD, DWRLD), \quad (1)$$

where EXPDEMj = demand for country j's export,
PEXPj = price of country j's exports,
PWRLD = world price of competing vegetable oils, and
DWRLD = world demand for vegetable oils.

Given the inability to observe country export prices, export unit values are chosen to represent PEXPj. PWRLD is the average price of world vegetable oils exports. The world demand variable DWRLD does not include exports from AGC countries.

Country supply of exports is expressed as a function of the real exchange rate for groundnuts and of the level of productive capacity of the domestic economy. The level of gross national product has been chosen as a proxy for the productive capacity variable. The choice is straightforward, given the role of groundnuts in the agricultural sector and of oil processing in the industrial sector of most AGC countries. Secular changes in the economy's productive capacity are normally associated with advances in factor supplies and productivity, and with improvement in overall infrastructure, all of which tend to raise exports at any given level of incentives (Goldstein and Khan 1985). The estimated supply equations are accordingly:

$$EXPSUPj = f(RERGNTj, NATGDPj), \quad (2)$$

and

$$RERGNTj = (PEXPj*NERj)/PDOMj, \quad (3)$$

where EXPSUPj = export supply from country j,
RERGNTj = real exchange rate for groundnuts in country j,
NATGDPj = level of productive capacity in country j,
PEXPj = price of country j's exports,
NERj = country nominal exchange rate, and
PDOMj = domestic price of nontraded goods.

The real rate of exchange reflects the relative incentives facing groundnut production and exports. It is defined as the ratio between the domestic price of groundnuts and the price of nontraded goods in each AGC country. The domestic price of groundnuts is given by the export price PEXPj multiplied by the nominal (domestic currency to the dollar) exchange rate NERj. Country consumer price indexes are used for the domestic price of nontraded goods.

Imposing the equilibrium condition (EXPDEMj = EXPSUPj) and normalizing equation (2) for the price of exports, the export demand and supply parameters can be estimated simultaneously. Equations (1) and (2) are specified in a log-linear form, meaning that the estimated supply and demand parameters correspond to the elasticities of demand and supply with respect to changes in the exogenous variables. In the demand equation, the parameter for the ratio of country j's export supply price to the world price of competing exports is expected to have a negative sign. The estimated parameter for the world demand variable will reflect the impact external demand has had on AGC countries export performance. In the case of

Table 7. Groundnut export demand and supply for selected AGC countries.

	PEXPj/PWRLD[1]	DWRLD	NATGDP	RERGNT	$\bar{R}^2$
Gambia					
EXPDEMj	-2.44	-0.54			0.17
	(-3.82)	(-0.78)			
EXPSUPj			-1.69	0.85	0.53
			(-5.33)	(2.10)	
Senegal					
EXPDEMj	-4.30	-0.39			-0.59
	(-2.42)	(-0.46)			
EXPSUPj			3.02	0.33	0.19
			(2.78)	(0.88)	
Sudan					
EXPDEMj	-1.0	-2.65			0.03
	(-3.14)	(1.13)			
EXPSUPj			7.46	0.36	0.45
			(4.46)	(1.61)	

1. See text for explanation of variable names.

external demand constraint the estimated parameter would have a negative sign.

In the supply equation, the coefficient of the real exchange rate variable is expected to have a positive sign, as increased domestic incentives would raise production for exports. Similarly, the sign of the coefficient of the productive capacity variable will be positive, as advances in productivity and improvement in infrastructure will lead to increases in the supply of exports.

Equations (1) and (2) have been estimated using data from 1966 to 1987 for Gambia, Senegal, and Sudan (the member countries that have exported consistently over the study period), using a 2-stage-least-square technique. The results are reported in Table 7. On the demand side, the parameters for the world demand variable have a negative sign, but none of them is significantly different from zero and, therefore, do not support the hypothesis of an external demand constraint. The high and strongly significant coefficients of the price variable, on the other hand, suggest a strong responsiveness of export demand to changes in relative export prices. The high elasticity values in particular stress the vital role of cost-reducing technological advance in an export sector faced with stagnating external demand. They also suggest that the large differences in yield increases between AGC countries and Asian and South American exporters reported in Table 6 may have played a key role in the loss of market shares suffered by AGC countries.

On the supply side, the coefficients for the capacity variable have the expected positive sign, and are high and strongly significant for Senegal and Sudan. It is lower and negative for Gambia. The shift in the sign of the coefficient may be explained by the problems associated with using GDP as a proxy for domestic productive capacity.

The real exchange rate coefficient captures the empirical relationship between relative incentives and groundnut export performance in AGC countries. It is insignificant only in the case of Senegal, a fact that may reflect the impact of the longstanding practice in that country of not transmitting changes in international prices to the domestic sector. It has, however, the expected positive sign for all three countries. Consequently, it would seem that groundnut exports have suffered from real exchange rate misalignments in these countries prior to the decade of the 1980s, as pointed out in a number of studies (Oyejide 1989; Gulhati et al. 1985; Elbadawi 1988; World Bank 1987).

Recalling the results for the export demand equation, the coefficients of the external demand variable in the export equations all have a negative sign. Assuming the continuation of past trends, this is an indication that future growth in international demand may not stimulate groundnut oil exports and that competition will increase considerably in foreign markets. Officials at AGC, as well as national policy makers, are now wondering whether regional markets could ease the pressure from stagnating overseas markets, should the domestic policy environment improve and the falling trend in production of member countries be reversed. The attempt to answer that question is undertaken in the section below.

Regional Markets and the Future of AGC Groundnut Exports

AGC groundnut exports are analyzed within the context of global oilseed trade and with particular attention to the West African market, using a simple constant-market share model. The model isolates the contribution of three different factors to the change in global export shares of individual AGC countries: 1) the competitiveness of individual countries in different oilseeds markets; 2) the relative expansion of demand in individual oilseeds markets; and 3) the geographic orientation of country exports (for explanation see model presentation in Appendix 1). It decomposes the changes in country export shares into three components:

$$\text{Competitive effect: } \frac{(1 + g_i^m)}{(1 + g_i^w)} \qquad (4)$$

This effect expresses the contribution of changes in a country's competitiveness in a given oilseed market to the change in its global trade performance. The effect is positive (negative) if the above ratio is greater (less) than 1.0 for the country under consideration.

$$\text{Product effect: } \frac{(1 + g_i^w)\, x_{it_0}^m}{(1 + g^w)\, x_{t_0}^m} \qquad (5)$$

The product effect reflects the contribution of changes in single product markets to the change in the global market share of a country. The effect is positive for a given country if it tends to have, in its exports, a high percentage of products that experience faster growth rates compared to the world average.

$$\text{Market effect: } \frac{(1 + g_j^w)\, x_{jt_0}^m}{(1 + g^w)\, x_{t_0}^m} \qquad (6)$$

This last component indicates the impact of the geographic orientation of a country's exports on the growth of its trade share. The effect is positive if a country directs a large share of its exports to markets that grow more rapidly than the world average.

Besides allowing one to single out the past and potential role of regional markets, the model can also be used to test the external demand constraint hypothesis. For instance, the external demand constraint would imply g_i^w (rate of growth of world demand) not exceeding g_i^m (country export growth rate) or, equivalently, a competitive effect not below unity. Similarly, the product effect is very helpful in highlighting the change in composition taking place in world demand for vegetable oils. A low product effect would reflect the slower growth of world demand for groundnut products compared to all vegetable oil products.

The model has been calculated for AGC countries, focusing only on groundnuts for the competitive and product effects, and on the African region for the market effect. The results presented in Table 8 (second column) show a negative competitive effect for all AGC countries. This indicates that AGC members have not been able to maintain their initial shares in world groundnut markets over the last three decades. The loss in competitiveness has been substantial for both Niger and Nigeria, even though Nigeria had an initial trade share that exceeded 20% of total world groundnut exports (Table 6). Thus, the competitive effect confirms the results from the previous export demand and supply estimations for the two other AGC countries not covered there. They show that the groundnut sector in AGC countries may have suffered more from falling competitiveness than from negative trends in world groundnut markets.

The third and fourth columns of Table 8 refer to the product-specific contribution of groundnuts to the changing role of AGC countries in international oilseed and oilfruit product markets. With the exception of Nigeria and Sudan, groundnut products make up to 90% or more of AGC countries' exports of oilseed products. The growth rate of world groundnut exports, however, has been less than 50% of that for the aggregate of oilseed commodities. The stronger growth for nongroundnut oilseed products would explain why a groundnut exporter could lose shares in total vegetable oils markets, but not necessarily in groundnut markets. It is important to note that the relative fall in demand for world groundnut products reflects to a large extent the fall in exports from AGC countries, which still account for nearly 30% of world exports (Table 6).

The market effect (last two columns of Table 7) displays the contribution of African markets, as a

Table 8. Market share results (1962–1987).

Country	Average share[1] (1962/67) (%)	Competitive effect[2]	Product effect[3]		Market effect[4]	
			Relative growth rate	Share	Relative growth rate	Share
Gambia	**0.4**	0.845	0.406	**0.839**	**2.523**	-[5]
Mali	**0.2**	0.387	0.406	**0.894**	2.523	0.23
Niger	**0.5**	0.000	0.406	0.962	2.523	0.157
Nigeria	**7.4**	0.001	0.406	0.541	2.523	-
Senegal	**3.3**	0.408	0.406	0.890	2.523	0.031
Sudan	1.9	0.510	0.406	0.367	2.523	-

1. Share in world exports of oilseeds and oilfruits products.
2. Relative growth rate of country export of groundnut products compared to world average. Values greater than unity mean a positive competitive effect.
3. Growth rate and share refer to groundnut products compared to other oilseeds and oilfruits products exports.
4. Growth rate refers to African imports of oilseeds and oilfruits products compared to world imports. The shares refer to the share of Africa in countries oilseeds and oilfruits products exports.
5. Countries either did not export to the region, or data on regional exports were not available.

Source: IFPRI Database and FAO trade yearbook, various issues.

destination of AGC countries' exports, to the change in their overall trade share. It reveals that AGC countries hardly export to African markets. The African share in the exports of the largest AGC exporter, Senegal, is as low as 3%. Demand in African markets, however, grew more than two and a half times faster than in world markets during the study period. It seems, therefore, that a stronger orientation of AGC exports to regional (African) markets would have stimulated exports more than stagnating overseas markets did.

However, whether the fast-growing regional markets can help boost future AGC exports will depend primarily on the changes in the level and composition of regional vegetable oils demand and on the competitiveness of AGC exporters on these markets.

Over the last three decades, African markets have continuously raised their share in world imports of two major vegetable oils, palm oil and groundnut oil (Fig. 2). At the same time, the share in world exports of AGC exporters fell by two-thirds (Fig. 3). As in overseas markets, most of the increase in import demand to African markets has been captured by competing vegetable oils such as palm oil. The shift in the relative share of individual oil products shows noticeable differences among subregional markets, however. As can be seen from Figures 4 and 5, import demand for groundnut oil has been growing much faster in the West African submarket, whereas the bulk of the increase in palm oil import demand went to other parts of the continent. As a result, the ratio of palm oil to groundnut oil imports for the regional submarket is about 16, close to the world average of 12, compared to 32 for the aggregate of Africa (Table 8). The observed geographic differences in the evolu-

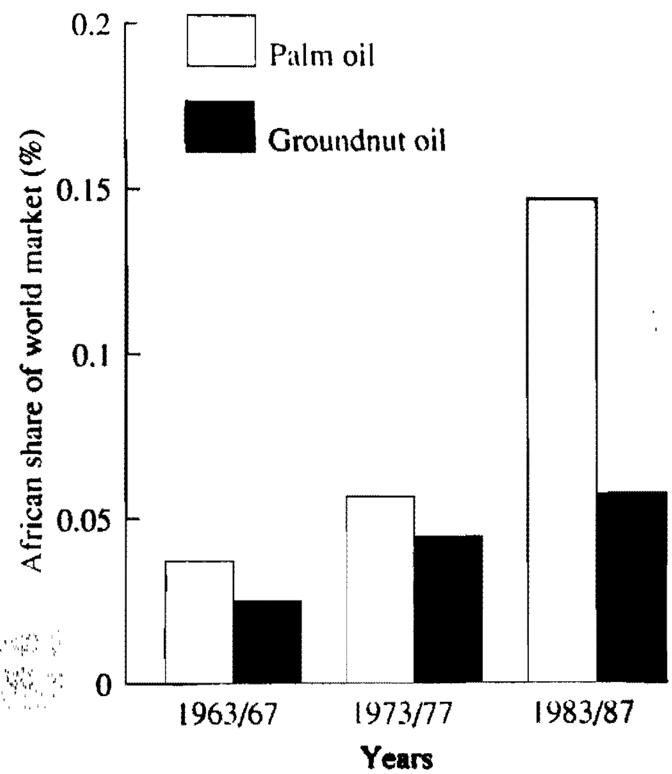


Figure 2. Share of Africa in world imports of palm oil and groundnut oil (1963-1987). (Source: IFPRI Database.)

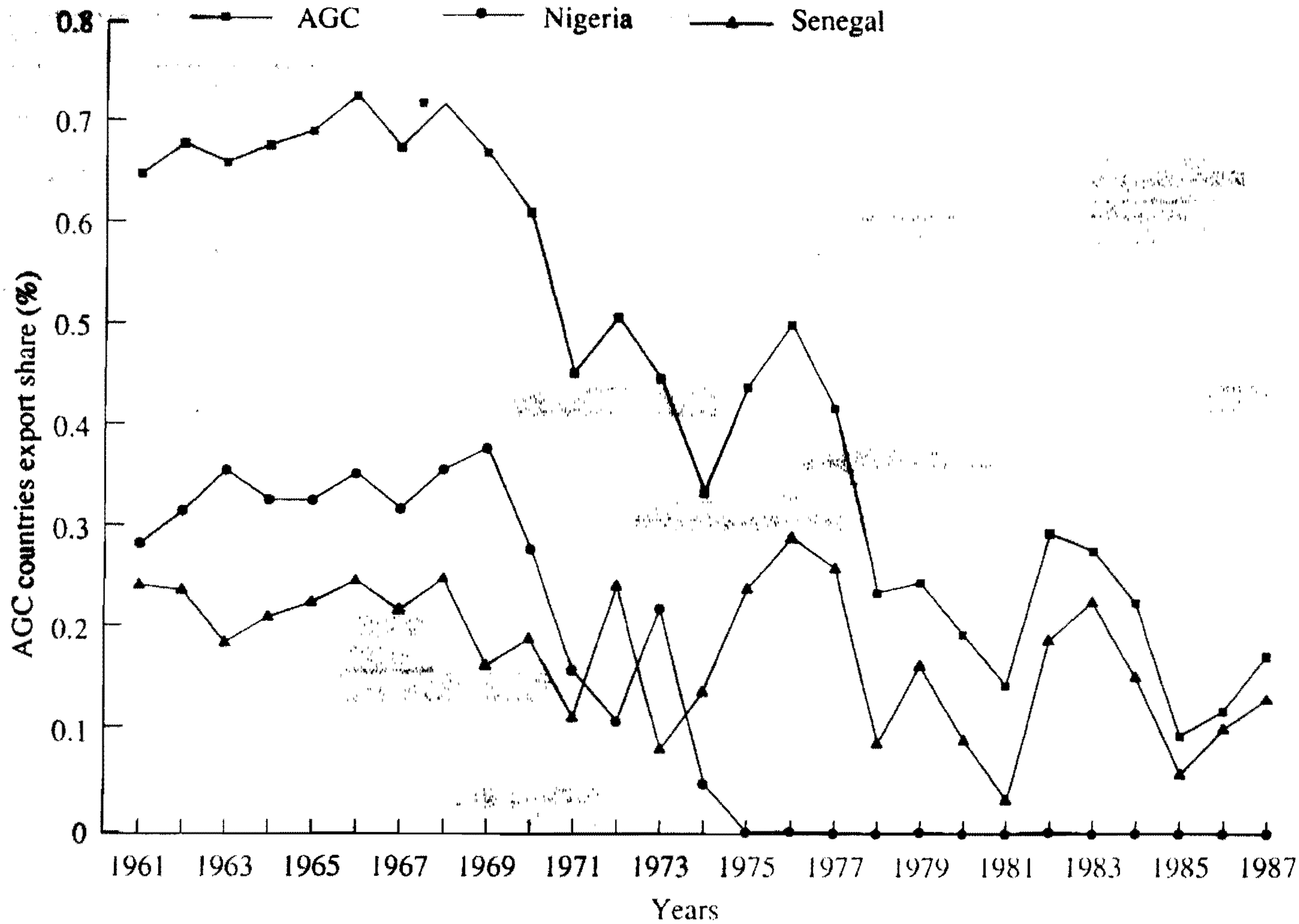


Figure 3. Export share of African Groundnut Council (AGC) countries for groundnut oil (1961–1987). (Source: IFPRI Database.)

tion of vegetable oils demand are very important since five out of the six AGC members, as well as the main exporting country, Senegal, are all located in West Africa.

Figures 2 and 3 show that the surge in palm oil demand is a very recent phenomenon, especially in West Africa. This evolution has a lot to do with the poor performance of the groundnut sectors in the region. Groundnut production in AGC countries has been declining by nearly 3% a year between 1962 and 1987, while world production of palm oil increased at an annual rate of 8% during the same period (Kintch and Badiane 1990). More importantly, the dramatic fall in groundnut exports from Nigeria (Fig. 3), now the largest vegetable oil importer of the region, has been a major boost to palm oil imports into the region.

The data recorded in Table 9 indicate that groundnut oil imports by all African countries and the West Africa region during the 1980s amounted to 20% and 8% of total AGC exports, respectively. These relatively small percentages would appear to put into question the role of regional markets in the future of the groundnut economy in AGC countries. AGC countries, however, currently export very little to African markets. The share of African markets in the exports of AGC's main exporting country, Senegal, has been as low as 3% (Table 7).

A more appropriate way of gauging the potential role of regional markets as a destination of AGC exports would be to look at what the demand on these markets may be in the future. This is done in the present section by estimating the main determinants of vegetable oils in the West African region. Aggregate import demand for vegetable oils is expressed as a function of the average import price, per capita income, the ratio of urban to total population, and of the capacity to import, as given by equation (7).

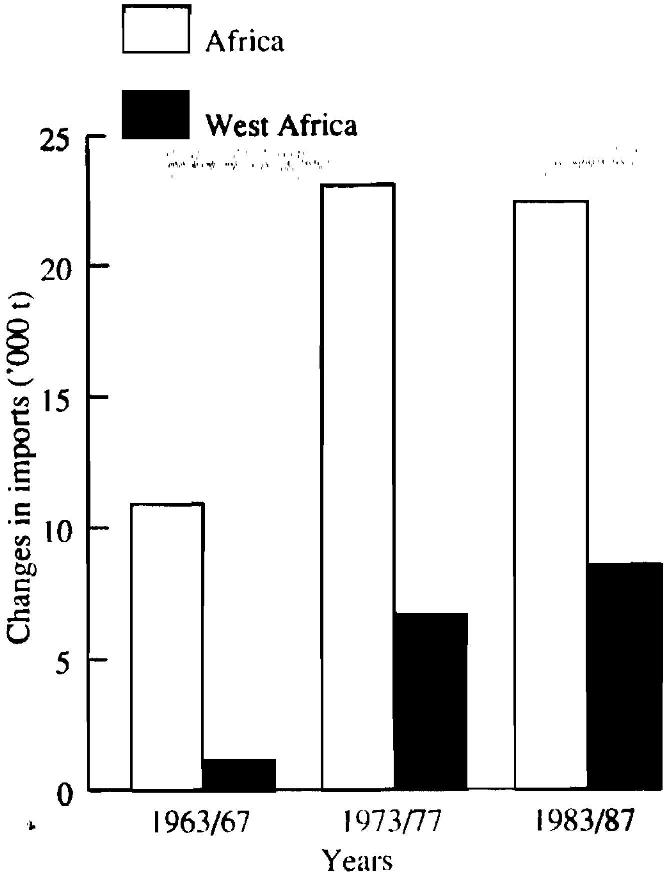


Figure 4. Changes in groundnut oil imports for Africa and West Africa (1963-1987). *West Africa includes only the main importers, i.e., Côte d'Ivoire, Ghana, and Nigeria.* **(Source: IFPRI Database.)**

MVGOL = f(PVGOL, INCOM, URBAN, EXREV), (7)

where PVGOL = import price of vegetable oils,
MVGOL = per capita import of vegetable oils for the region,
INCOM = per capita income for the region,
URBAN = ratio of urban to total population for the region, and
EXREV = per capita export revenue for the region.

The share of individual vegetable oils in aggregate demand is in turn determined by the own price, the average price of other oils, income, the capacity to imports, and the share of urban population as follows:

MPORTi = f(OWNPRi, OTHPRj, EXREV, URBAN, INCOM) (8)

where MPORTi = per capita demand of vegetable oil i,
OWNPRi = import price of vegetable oil i, and
OTHPRj = average import price of other vegetable oils.

The demand for vegetable oils is known to increase rapidly with rising income levels. Given the actual level of income in West Africa, the demand for vegetable oils including imports can, therefore, be expected to remain highly income elastic. Also, demand for imports will tend to increase with increasing capacity to import, represented here by the variable per capita export revenue (Hemphill 1974). Furthermore, the share of urban population is expected to raise the demand for vegetable oils imports for two reasons. First, demand in urban centers tend to have a higher content of superior goods such as vegetable oils. Second, the fact that the major urban centers in West Africa are in most cases coastal port cities will tend to raise the import content of urban demand for such goods.

Equations (7) and (8) are estimated in log-linear form, so that the price and income parameters can be interpreted as demand elasticities. The price coefficients may be biased, however, for the following reasons. First, unit values are used as proxies for import prices causing a downward bias of elasticity estimates (Kmenta 1971). Second, not including the domestic price of competing substitutes leads to an upward bias

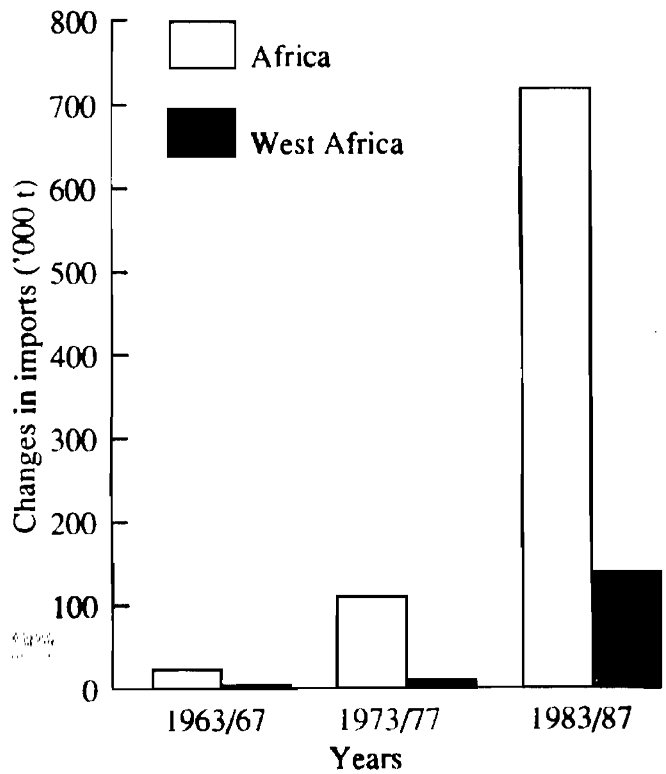


Figure 5. Changes in palm oil imports for Africa and West Africa (1963-1987). *West Africa includes only the main importers, i.e., Côte d'Ivoire, Ghana, and Nigeria.* **(Source: IFPRI Database.)**

Table 9. Groundnut and palm oil imports by West African and other African countries.

Regions	Years 1963–67	1973–77	1983–87
		Vegetable Oil Imports (t)	
World			
Groundnut oil	438 208.0	513 080.0	393 421.0
Palm oil	626 562.2	1 930 343.8	4 888 495.2
Africa			
Groundnut oil	10 955.2	23 088.6	22 425.0
Palm oil	23 182.8	110 029.6	718 608.8
West Africa			
Groundnut oil	1 169.4	6 728.0	8 603.6
Palm oil	3 654.2	9 561.6	138 640.0
		Groundnut Oil Exports (t)	
West Africa[1]	240 066.0	227 863.8	112 443.8
AGC[2]	240 500.4	236 156.6	117 679.8
Senegal	136 837.8	172 414.6	102 932.6

1. West Africa includes Gambia, Mali, Niger, Nigeria, and Senegal.
2. AGC members include the five countries above plus Sudan.

of the estimated price elasticity of aggregate imports (Bautista 1978). Third, cross-equation restrictions were not imposed in order to ensure that the regression coefficients satisfy cross-elasticity conditions.

Equation (7) was estimated using aggregated import data for the three major vegetable oils imported into West Africa: groundnut oil, palm oil, and soybean oil. The negative sign of the parameter for the import capacity variable (EXREV) suggests an inverse relationship between export earnings and country import of vegetable oils (Table 10). A possible explanation of this behavior is that periods of high export earnings in the typical West African importing country tend to coincide with periods of reduced import requirements. This is due to the fact that the countries concerned are, themselves, major oilseed producers, and aggregate regional exports have a high agricultural content.

The own-price elasticity has the correct sign but is not significantly different from zero. The urban and income variables, on the other hand, show high and strongly significant coefficients. Given the rapid change characteristic of these two variables, these results indicate that regional demand for vegetable oils is likely to maintain the high growth rates of the past two decades, or even accelerate, as the region's economies recover from the economic crisis of the 1970s and 1980s.

The extent to which regional import growth will stimulate regional (AGC) groundnut exports will depend on the distribution of demand expansion across individual vegetable oils. This can be studied by looking at the factors that affect the composition of regional demand vegetable oils imports. For this purpose, equation (8) was estimated for each of the three vegetable oils by replacing the left-hand side variable MPORTi through the share in total imports of groundnut, palm, and soybean oil, SHGNT, SHPLM, and SHSOY, respectively in Table 10. The three import equations can be thought of as describing processes by which consumers demand a desired amount of vegetable oils by choosing quantities of individual oils that minimize their combined cost. This would imply that error terms are probably correlated across single equations (Johnston 1984). In order to obtain efficient estimates of the regression coefficients in this case, Zellner's seemingly unrelated regression method was applied here (Zellner 1962).

The first three rows of Table 10 present the results for groundnut oils and the two other competing vegetable oils, palm oil and soybean oil. According to the figures, the share of groundnut oil in imported vegetable oils is very sensitive to changes in its import price, and more so than the other two vegetable oils with respect to their prices. To the extent that the

Table 10. Regression estimates of import demand for vegetable oils in West Africa[1].

	OWNPR[2]	OTHPR	EXREV	URBAN	INCOM	$\bar{R}^2$	F
SHGNT	-2.33	0.65	-0.26	-9.53	7.95	0.61	7.06
	(-2.93)	(0.55)	(-0.33)	(-3.10)	(1.62)		
SHPLM	-1.56	1.36	-0.52	3.79	-0.11	0.63	7.45
	(-1.98)	(1.99)	(-0.98)	(2.12)	(-0.03)		
SHSOY	-0.96	1.06	-0.54	-5.52	5.86	0.66	8.46
	(-1.69)	(1.46)	(-0.97)	(-2.61)	(1.73)		
VGTOL[3]	-0.48		-0.78	4.19	4.94	0.82	23.02
	(-0.74)		(-1.68)	(2.52)	(2.16)		

1. West Africa includes only main importers: Côte d'Ivoire, Ghana, and Nigeria.
2. See text for explanation of variable names.
3. Durbin-Watson statistic for this equation is 2.24. System-weighted R-square for the first three equations is 0.62.

estimates in the second column can be interpreted as cross-elasticities, they suggest that West African consumers have reacted to relative price changes by substituting palm oil for other vegetable oils and by shifting the vegetable oil import balance in favor of the former. Palm oil import demand has also benefitted from rapid urbanization in West Africa, at the expense of its competitors. Normally, the urban population expands more rapidly in its lower income section, where demand for the relatively 'inferior' oil type may be more buoyant (see income elasticity estimate).

The income coefficients, on the other hand, indicate a significant demand potential for groundnut oil and, to a lesser extent, soybean oil. As the price coefficients clearly signify, however, AGC groundnut exporters will have to sustain or even improve their price competitiveness to benefit significantly from economic recovery in importing countries. In case of continued economic stagnation, groundnut exporters will face tremendous price pressure to compete with palm oil.

Summary and Conclusions

Although in some cases it is still significant, the contribution of the groundnut sector to the economies of AGC countries has diminished consistently since the 1960s. Both production and exports have fallen sharply over the last two decades. These dramatic changes in the groundnut economies have often been portrayed as a result of diminishing demand on international markets.

The data presented in this study show that the decline in AGC exports between the 1960s and the 1980s was three times as large as the fall in global groundnut oil exports, which was around 50 000 t. Consequently, the decline in AGC export performance can hardly be explained by reduced external demand. The data also show that global demand for vegetable oils has tilted significantly in favor of competing vegetable oils, because their exports grew twice as fast as that of groundnut oil. Although this tendency may have raised some doubt about long-term prospects for groundnut oil relative to other vegetable oils, it should not have much impact on the performance of individual exporters on world groundnut markets.

The share of AGC countries in world groundnut exports fell by more than 50%, while exporters from South American and Asian countries more than quadrupled their combined share over the last three decades. The loss in market share was also accompanied by a continuous decrease in yield and acreage in AGC countries, contrasted with strong yield increases in competing Asian and South American countries. It would seem, therefore, that AGC exports have suffered more from domestic than external demand factors.

The above hypothesis has been tested by estimating a simultaneous supply and demand model for groundnut oil exports by the primary AGC exporters, Gambia, Senegal, and Sudan. The results obtained suggest that country exports have been more sensitive to relative price shifts and changes in domestic incentives, as indicated by the sectoral real exchange rate, than to global trends in vegetable oils demand.

With the recent trade policy debates in West Africa the idea of recapturing regional vegetable oils markets to compensate for dwindling international outlets has received increased attention. The role of regional markets for exports of groundnuts from AGC countries has been investigated, using a constant market share model. Besides confirming the previous results of the econometric model that the groundnut sector in AGC countries has been hurt more by falling competitiveness than by changes in foreign demand, the model outcome revealed that the latter countries hardly exported to regional markets, on which demand grew at a rate two and a half times faster than on world markets.

The trade data gathered under the study showed that groundnut oil imports to African markets amounted to 20% of total AGC exports in the 1980s, 50% of which went to the West African submarket. These numbers seem small and may put to question the role regional markets can play as potential outlets for AGC exports, unless regional demand continues to grow at the nearly two-digit rates of the last decades. In order to have an idea about how fast regional markets may expand in the future, equations for total import demand and for the share of the three main vegetable oils (groundnut, palm, and soybean) in aggregate imports have been estimated. The derived elasticities with respect to the urbanization and income variables imply a significant potential for demand expansion. The share of groundnut oil appears to grow significantly faster with incomes than the other two oils. The high elasticity of the share with respect to the own price of groundnut oil shows how much AGC exporters would have to gain in terms of regional outlets if they succeeded in reversing the declining trend and cutting domestic costs of production.

Acknowledgment

This paper benefitted from the very able research assistance of Gay Mandour.

References

Bautista, R. 1978. Import demand in small country with trade restrictions. Oxford Economic Papers 30:199-216.

Elbadawi, I.A. 1988. Foreign trade, exchange rate, and macroeconomic policies and the growth prospects for Sudanese agriculture. New Haven, Connecticut, USA: Yale University, Economic Growth Center.

Goldstein, M., and **Khan, M.S.** 1978. The supply and demand for exports: a simultaneous approach. Review of Economics and Statistics 60:275-286.

Goldstein, M., and **Khan, M.S.** 1985. Income and price effects in foreign trade. Pages 1042–1105 *in* Handbook of international economics (Jones, R.W., and Kenen, P.B., eds.). Vol. 2. New York, USA: Elsevier.

Gulhati, R., **Bose, S.**, and **Atukorala, V.** 1985. Exchange rate policies in eastern and southern Africa, 1965-1983. Staff Working Paper no. 270. Washington, D.C., USA: World Bank.

Hemphill, W.L. 1974. Pages 637–676 *in* The effects of foreign exchange receipts on imports of less developed countries. Staff Papers Vol. 21. Washington, D.C., USA: International Monetary Fund.

Johnston J. 1984. Econometric methods, 3rd edition. New York, USA: McGraw-Hill Book Co.

Kinteh, S., and **Badiane, O.** 1990. The market potential for groundnut products facing West African countries and the possible role of regional markets. Washington, D.C., USA: International Food Policy Research Institute.

Kmenta, J. 1971. Elements of econometrics. New York, USA: Macmillan.

Magee, S. 1975. Prices, income and foreign trade. Pages 175–243 *in* International trade and finance: frontiers for research (Kenen P.B., ed.). Cambridge, UK: Cambridge University Press.

Oyejide, T.A. 1989. Effects of trade and macroeconomic policies on agricultural incentives in Latin America. Pages 12.1-12.27 *in* Trade and macroeconomic policies in developing countries: impact on agriculture (Bautista, R., and Valdes, A., eds.). Washington, D.C., USA: International Food Policy Research Institute.

WB (World Bank). 1987. World development report 1987. Washington, D.C., USA: WB.

Zellner, A. 1962. An efficient method of estimating seemingly unrelated regressions and tests for aggregation bias. Journal of the American Statistical Association 57:348-368.

Appendix 1

The adopted model, similar to the one developed in Magee (1975), starts with the following identity:

$$S_{t_1} = R \cdot S_{t_0} \tag{a1}$$

where S_{t_0} and S_{t_1} denote, the shares of a given member country in total world exports of oilseeds in the beginning period (1962–67) and end period (1982–87), respectively. R represents a relative growth factor defined as follows:

$$R = \frac{(1 + g^m)}{(1 + g^w)} \tag{a2}$$

where g^m and g^w stand for the percentage growth rates of total exports of oilseed and oilfruit products of country m and the world w between the beginning and the end period, respectively. Equation (a2) expresses the growth of country m's exports (X^m) relative to world exports and can be rewritten as:

$$R = \sum_i \frac{(1 + g_i^m)}{(1 + g^w)} \frac{(X_{it_0}^m)}{(X_{t_0}^m)} \tag{a3}$$

with $X_t^m = \sum_i X_{it_0}^m$. By expressing X for the different products, i, and different export destinations, j, in equation (a3), multiplying by $[(1 + g_i^w)/(1 + g_i^w)]$ and by $[(1 + g^w) X_{t_0} /(1 + g^w) X_{t_0}^m]$, summing over i and j, and rearranging the terms, the result is the following:

$$R = \sum_i \frac{(1+g_i^m)}{(1+g_i^w)} \frac{(1+g_i^w)}{(1+g_i^w)} \frac{X_{it_0}^m}{X_{t_0}^m} \sum_j \frac{(1+g_j^w)}{(1+g^w)} \frac{X_{jt_0}^m}{X_{t_0}^m} \tag{a4}$$

with $X_{t_0}^m = \sum_i X_{it_0}^m = \sum_j X_{it_0}^m$, and i and j representing individual oilseed and oilfruit products and export destinations, respectively. By substituting equation (a4) for R in equation (a1), the result is a new expression for the change in country export shares between 1962–67 and 1982–87:

$$S_{t_1} = S_{t_0} \sum_i \underbrace{\frac{(1+g_i^m)}{(1+g_i^w)}}_{a} \underbrace{\frac{(1+g_i^w)}{(1+g_i^w)}}_{b} \frac{X_{it_0}^m}{X_{t_0}^m} \underbrace{\sum_j \frac{(1+g_j^w)}{(1+g^w)}}_{c} \frac{X_{it_0}^m}{X_{t_0}^m} \tag{a5}$$

It is clear from equation (a1) that the direction of a country's export share during a given time period depends on whether the relative growth factor R is greater, less than, or equal to unity. Furthermore, the new expression for R in equation (a5) shows that a country may increase its global trade share because 1) it has been able to raise its exports in single product markets faster than the world average [term a of (a5); 2] its exports are concentrated on the commodities that experience faster growth rates than the aggregate of oilseeds and oilfruits products (the last two terms of the first sum); and 3) its exports are directed more toward the markets that grow faster than the world average [term c (a5)].

Discussion

K.S. Vara Prasad: What are the reasons for the increase in groundnut food use in Europe? Are there any specific products which have contributed to this?
S.M. Fletcher: The USA has pushed peanut butter and other products for use as snack food in the European market.

Y.C. Joshi: What are the reasons for low yields obtained after 1985 in the USA?
T.G. Isleib: Droughts in the southeastern USA, which has the largest groundnut production area, have affected the average yield in the country.

Regional Reviews

Groundnut Production and Research in North America

T.G. Isleib and J.C. Wynne[1]

Abstract

*The primary groundnut (*Arachis hypogaea*)-producing countries of North America are Mexico and the United States, with the USA producing the majority of the crop. Unlike Mexico, production of groundnuts in the USA is almost completely mechanized and utilizes high inputs because of guaranteed price supports. Groundnut's high value and use as a food crop have made possible the development of an extensive research infrastructure supported by both public and private funding. Most research on groundnuts in the USA is conducted by the U.S. Department of Agriculture and state experiment stations in nine states of the southeastern and southwestern USA. Less extensive research on the crop is conducted in Mexico and in Canada where there is interest in adapting the crop to the short growing season there. Research in the USA during the last decade has emphasized the production of high quality groundnuts at lower costs to the farmer. Research in Mexico has focused on increasing production while research in Canada has attempted to adapt the crop to local growing conditions.*

Résumé

Production et recherche d'arachide en Amérique du Nord: *Les plus importants pays producteurs d'arachide (*Arachis hypogaea*) en Amérique du Nord sont le Mexique et les Etats-Unis, les Etats-Unis produisant la majorité de cette culture. Contrairement au Mexique, la production d'arachide aux Etats-Unis est presque complètement mécanisée et utilise des intrants très forts, en raison de la garantie des prix de soutien. La valeur élevée de l'arachide et son usage comme culture vivrière ont permis de mettre au point une infrastructure de recherche importante, appuyée par un financement public et privé à la fois. La plupart des recherches sur l'arachide aux Etats-Unis sont effectuées par le Ministère de l'Agriculture et des stations expérimentales dans neuf états de la région sud-est et sud-ouest. Des recherches moins étendues sur la culture sont effectuées au Mexique et au Canada, où l'on s'intéresse à adapter cette culture à la saison de croissance très courte de ce pays. La recherche aux Etats-Unis pendant la dernière décennie a mis en relief la production d'arachide de haute qualité à un coût plus faible pour le cultivateur. La recherche au Mexique est axée sur une augmentation de la production, tandis que le Canada essaie d'adapter la culture aux conditions locales de croissance.*

Production

The majority of groundnuts (*Arachis hypogaea*) produced in North America are grown in nine states in the southeastern and southwestern USA. The other major groundnut-producing country in North America is Mexico, which produced from 50 000 to 103 000 t during the decade beginning in 1980 (Table 1). Groundnut production in the USA ranged from 1.5 to 2.0 million t with the area sown to groundnuts

1. Associate Professor and Professor, Department of Crop Science, North Carolina State University, P.O. Box 7629, Raleigh, NC 27695-7629, USA.

This paper was made possible through support provided by the Office of Agriculture, Bureau of Research and Development, U.S. Agency for International Development, under Grant No. DAN 4048-G-00-0041-00.

Isleib, T.G., and Wynne, J.C. 1992. Groundnut production and research in North America. Pages 57–76 *in* Groundnut – a global perspective: proceedings of an international workshop, 25–29 Nov 1991, ICRISAT Center, India (Nigam, S.N., ed.). Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Table 1. Harvested area and production of groundnuts in North America, 1980-88.

	Year								
Country	1980	1981	1982	1983	1984	1985	1986	1987	1988
					Harvested area ('000 ha)				
USA	615	602	516	556	620	594	622	626	659
Mexico	38	47	45	45	40	43	45	40	85
					Production ('000 t)				
USA	1690	1806	1560	1495	1998	1870	1679	1642	1806
Mexico	72	73	50	65	55	65	60	55	103

Source: USDA 1983-89.

Table 2. Groundnut coverage and yields per hectare by states and regions of the USA, 1987-1990.

	Area ('000 ha)				Yield (kg ha^{-1})			
Region/State	1987	1988	1989	1990	1987	1988	1989	1990
Southeast								
Alabama	89.1	96.4	96.8	103.7	2369	2912	2520	1702
Florida	33.6	35.2	35.2	37.3	2912	2912	1766	2688
Georgia	255.2	279.5	277.4	309.8	2800	3024	3024	1971
Total	377.9	411.1	409.4	450.8	2694	2949	2770	2120
Southwest								
New Mexico	4.9	5.3	7.3	8.1	3024	3024	2688	2912
Oklahoma	39.7	42.5	39.7	43.7	2542	2352	2408	2520
Texas	102.1	101.3	106.1	115.4	1960	1848	2072	2111
Total	146.7	149.1	153.1	167.2	2509	2408	2389	2514
Virginia-Carolina								
N. Carolina	59.9	62.0	61.6	66.4	2968	3136	2727	3304
Virginia	36.5	38.1	36.9	39.3	3024	3360	3030	3472
S. Carolina	5.3	5.7	5.3	5.7	2688	2744	2912	2352
Total	101.7	105.8	103.8	111.4	2803	3080	2890	3043
USA	626.3	666.0	666.3	729.4	2622	2808	2717	2240

Source: USDA 1990a, 1990b.

remaining fairly constant over the decade because of government control of production. The average yield from 1987–1990 ranged from 2240 kg ha^{-1} to 2808 kg ha^{-1} (Table 2).

Production in the USA

Because most of the groundnuts produced in North America are produced in the USA, production and research in the USA will be emphasized. Groundnuts are grown in four principal areas. The largest production area is the Southeast, which includes the states of Alabama, Florida, and Georgia (Table 2). The runner market type, which is a small-seeded virginia (*Arachis hypogaea* subsp *hypogaea* var *hypogaea*), predominates in the region. The Virginia–Carolina area produces large-seeded virginias or confectionery types. The third production area, the Southwest, includes Texas and Oklahoma. The spanish (*A. hypogaea* subsp *fastigiata* var *vulgaris*) groundnut once predominated in this area; however, the higher yielding runners are now grown on much of the hectarage, especially the area that is irrigated. The fourth production area, New Mexico, grows valencias (subsp *fastigiata* var *fastigiata*) under irrigation and produces about 1% of the U.S. crop. About 70% of the U.S. crop is of the runner type, while virginia and spanish types constitute about 20% and 10% of the crop (Knauft et al. 1987).

U.S. government groundnut programs

While groundnuts are used primarily for vegetable oil in most of the world, in the USA they are grown mainly for food including peanut butter, roasted-in-the-shell, candy, and as shelled whole seeds that are salted or dry-roasted. Groundnuts used as food have a higher market value, with edible groundnuts having a higher world market price than oil. About 60% of the groundnuts in the USA were used for edible products in 1989 (USDA 1990a, 1990b). Groundnuts too poor in quality for food use and surplus groundnuts are crushed for oil and meal, which brings a reduced price.

There has been a U.S. price support program for groundnuts every year since 1934 except for 1936 (Carley 1983). For almost 40 years until 1980, the government established a minimum national allotment of 652 050 ha. At present, each farm is assigned a poundage quota. The quota is established to produce a supply that meets the anticipated demand. Only groundnuts within the poundage quota are eligible for price supports. Groundnuts grown in excess of the quota are 'additional' groundnuts. The price of additional groundnuts may range from about half that of quota groundnuts to prices equal to quota groundnuts during years of low production.

Cultural practices

Because of the guaranteed price for groundnut, farmers in the USA have been able to invest the capital necessary to completely mechanize the production of the crop. They are also able to utilize considerable inputs in order to produce high yields of good quality groundnuts. An example of estimated revenue, operating expenses, and net revenue per hectare for a typical North Carolina groundnut producer in 1990 indicates the return of the crop for the producer (Table 3).

Because of the high value of the crop, the U.S. groundnut grower gives careful attention to production practices in order to maximize profits and produce a quality product for the market. Planning begins far in advance of actual sowing of seed.

The Cooperative Extension Service of each groundnut-producing state develops detailed information on field selection including crop rotation, land preparation, cultivar selection, selection of seed and sowing, weed management, insect and disease control, fertilization, harvesting and curing, and marketing. This information is made available to growers through local meetings, television or radio, newspapers and magazines, and the preparation of annual production guides.

Groundnut production is completely mechanized; thus, a single grower can farm several hundred hectares. Given good weather, the grower relies primarily on chemicals for weed, insect, and disease control to ensure high yields. A special implement is used to dig and invert the crop, allowing it to dry in the field. When the pegs are sufficiently brittle for easy separation of the pods, the crop is combined. Subsequent drying is performed in trailers equipped with channels for the passage of forced air, usually heated by burning liquified propane (LP) gas. Although these practices are costly, the grower invests heavily to ensure high yield and quality. A change is now occurring in the USA. Public awareness of pesticide residues in food and the adverse effects of heavy use of pesticides and fertilizer on the environment have provided impetus to reduce the use of agrichemicals in U.S. agriculture.

Postharvest handling and utilization of groundnuts

The production, marketing, and processing system for groundnuts in the USA is influenced by the price support program (Davidson et al. 1982). Official procedures have been developed to determine the price for groundnuts delivered from the farm (farmer's stock). After the groundnuts have been dried, they are usually delivered to a buying station where they are graded and a value is assigned to the lot. The typical groundnut handling, marketing, and processing as outlined by Davidson et al. (1982) is shown in Figure 1.

After shelling, grading, and storage, most groundnuts are sold to manufacturers who produce edible products, the largest in the USA being peanut butter. Peanut butter generally contains 95% finely ground, blanched, dry-roasted groundnuts, with the additional 5% comprised of salt, hydrogenated vegetable oil, dextrose, antioxidant, honey, lecithin, whey, or other

Table 3. Estimated US$ revenue and operating expenses per hectare for a North Carolina groundnut grower, 1990.

	1990		1991		
Item	Cost ha^{-1} (US$)	% of total cost	Cost ha^{-1} (US$)	% of total cost	Change (%)
Crop insurance	61.77	5.1	74.13	5.2	+20.0
Fertilizer	197.26	16.4	211.07	14.7	+7.0
Lime	31.63	2.6	29.65	2.1	-6.3
Spreading charge	8.40	0.7	9.88	0.7	+17.6
0-10-20	73.83	6.1	85.99	6.0	+16.5
Landplaster	79.07	6.6	81.54	5.7	+3.1
Boron	4.32	0.4	4.00	0.3	-7.4
Fuel and lubricant	119.74	10.0	164.84	11.5	+37.7
Tractor	48.58	4.0	80.78	5.6	+66.3
Machinery	29.28	2.4	34.03	2.4	+16.2
Drying	41.88	3.5	50.04	3.5	+19.5
Maintenance	145.52	12.1	168.05	11.7	+15.5
Tractor	39.21	3.3	45.74	3.2	+16.6
Machinery	86.21	7.2	100.49	7.0	+16.6
Equipment	20.09	1.7	21.82	1.5	+8.6
Pesticide	461.95	38.5	561.58	35.9	+21.6
Fungicide	155.03	12.9	216.04	15.0	+39.4
Herbicide	91.33	7.6	120.34	8.4	+31.8
PI or preemergence	40.60	3.4	79.19	5.5	+95.1
Cracking	28.39	2.4	5.68	0.4	-80.0
Postemergence	22.34	1.9	35.46	2.5	+58.7
Insecticide	120.16	10.0	118.21	8.2	-1.6
Nematicide/fumigant	95.43	7.9	106.99	7.4	+12.1
Seed	214.97	17.9	259.45	18.0	+20.7
Total	1201.21	1439.12			
	(US$)		(US$)		Change (%)
Value of crop (based on 3590 kg ha^{-1})	2435.38		2482.83		+1.9
Return to land, quota, labor, capital, machinery, overhead, and management	1234.17		1043.71		-15.4

Source: Babcock 1990; Neuman 1991.

minor additives. The second largest amount of edible groundnuts is consumed as salted whole seeds. The third major use is in the production of confectionery products.

Production in Other North American Countries

In 1980, USDA Agricultural Statistics showed that groundnuts were produced in the USA (615 000 ha), the Dominican Republic (52 000 ha), Mexico (38 000 ha), and other countries in North America (4000 ha). However, by 1988 only the USA and Mexico continued to have significant areas sown to groundnuts (Table 1). In Mexico groundnuts are a minor crop. The crop is rainfed and yields are similar to those in the dryland areas of Texas. However, production of the crop is not highly mechanized in Mexico.

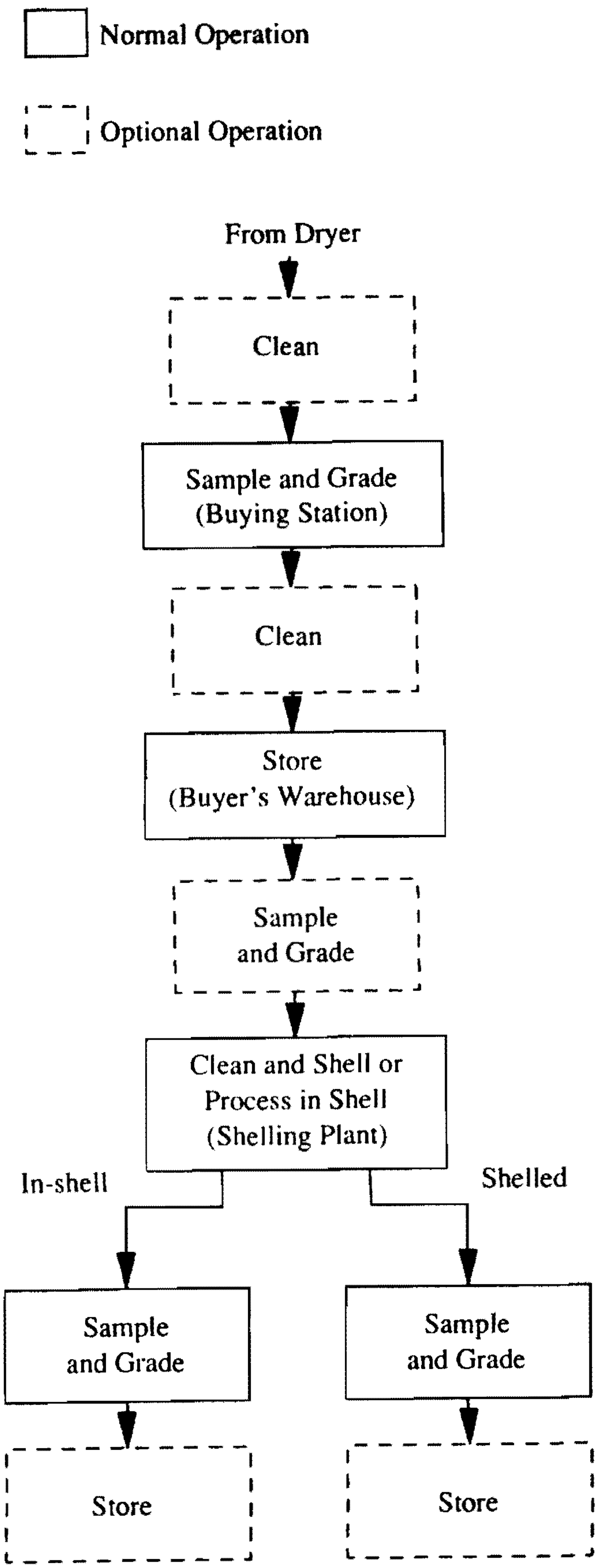


Figure 1. Typical groundnut handling, marketing, and processing system used in the USA. (Source: Davidson et al. 1982.)

Research in the USA

A substantial research infrastructure has developed in the USA to support the production, processing, and utilization of groundnuts. Development of this infrastructure required several decades. Woodroof (1983) has given an excellent description of the historical development of groundnuts as a crop and of the development of the groundnut industry in the USA.

Woodroof (1983) summarized the factors important in increasing the production of groundnuts in the USA. He refers to the evolution of mechanization, which has eliminated almost all hand labor in groundnut production and processing. Mechanization was stimulated by larger farms and the necessity for efficiency in performing field operations. The increase in production of groundnuts began with the need for oil, food, and feed during World War II. The accomplishments considered by Woodroof to be responsible for the increases in production in the USA can be summarized as follows:

1. Breeding programs that develop higher yielding cultivars adapted to mechanical harvesting,
2. Development of machinery to completely mechanize production,
3. Appropriate use of fertilizers based on soil tests and plant analyses,
4. Use of high-quality certified seed,
5. Use of herbicides to control grasses and weeds,
6. Use of irrigation,
7. Use of airplanes for spraying and dusting to control insects and diseases,
8. Improved methods of determining maturity,
9. Prompt digging, rapid drying, and storage to produce aflatoxin-free groundnuts, and
10. Improvement in roads and contour of fields so that large equipment can be used and groundnuts can be moved to storage facilities.

These changes in technology were dependent upon research and development undertaken to solve the constraints of all phases of the groundnut industry in the USA.

Research Organizations

Groundnut research is performed both by public agencies and by private industry in the USA. The majority of research is conducted b public agencies; however, the amount and the nature of research performed by private industry is difficult to quantify because of its proprietary nature.

Public agencies involved in groundnut research include the Agricultural Research Service of the United States Department of Agriculture (USDA-ARS) and state universities and experiment stations in the groundnut-producing states of the USA. A review of the Current Research Information System (CRIS) database of the USDA research project system indicates that groundnut research is currently being conducted by several public agencies, including:

- Auburn University,
- Alabama A&M University,
- University of Florida,
- University of Georgia,
- USDA Southern Regional Research Center, New Orleans,
- Dawson Peanut Lab (USDA),
- Savannah Insect Laboratory (USDA),
- ARS, USDA, Beltsville,
- New Mexico State University,
- North Carolina State University,
- Oxford Laboratory, North Carolina (USDA),
- Oklahoma State University,
- USDA, Mayaguez, Puerto Rico,
- Texas A&M University, and
- Virginia Polytechnic Institute and State University.

Most of the research by private industry is designed to develop new products or improve old products that can be commercialized.

Funding

Research is principally supported by funds allocated by the federal government through the USDA-ARS and Cooperative States Research Service (CSRS) and by state governments of the groundnut-producing states. Individual research projects can also receive funds from other federal agencies, private companies, and private foundations on a competitive basis. Private companies fund research at the various universities and at USDA laboratories through grants, contracts, or memoranda of agreement. A substantial amount of research funding originates from the growers of each groundnut-producing state. The growers in each state have organized themselves into groups that promote the use of groundnuts, and support research of a problem-solving nature. Funds for their activities are generated by levying a small fee per unit marketed.

During the last decade, significant funding for research has been provided by the U.S. Agency for International Development (USAID), which began funding of the Peanut Collaborative Research Support Program (Peanut CRSP) in 1982, and by the National Peanut Foundation. The National Peanut Foundation was established in 1986 to provide research funding to improve the quality of groundnuts and groundnut products. Contributions to the foundation come from industry associations, shellers and custom processors, brokers, manufacturers, associated industries, and individuals. Projects are funded annually and are selected according to their potential for long-term improvement of groundnuts and groundnut products. Many of the projects recently funded have involved a goal for the elimination of aflatoxin in groundnuts.

Programs and Progress

The remainder of this paper will be used to summarize research programs and progress that have been made in several areas during the past decade since the last international groundnut meeting held at ICRISAT in 1980. The summary of each area is not intended to be exhaustive but provides some insight into the progress and present research being conducted on groundnut in the USA. Much of the information was obtained by a computer search of the CRIS database.

Breeding and genetics

Considerable resources have been directed toward the genetic improvement of groundnuts in the USA (Table 4). Programs to develop new cultivars were among the first research efforts given to groundnuts in several states.

The collection, maintenance, and evaluation of groundnut germplasm have been high priorities in the USA. The transfer of R.N. Pittman from Oklahoma to Griffin, Georgia, as the first full-time groundnut curator (Table 4) has helped organize efforts in this area. During the last decade, breeders have identified considerable germplasm that could be used to improve the groundnut (Wynne and Halward 1989a). Collection expeditions during the past decade have continued to add to the diversity available for improvement of the groundnut (Simpson 1983, 1990).

Utilization of wild species. Utilization of the wild species of *Arachis* to improve the cultigen has been investigated in the USA by three research programs

Table 4. List of groundnut breeding and genetics and related projects compiled from USDA-CRIS.

Investigator(s)	Location[1]	Title
W.D. Branch	CPES	Peanut breeding and genetics
T.E. Cleveland A.K. Weissinger	SRCC and NCSU	Production and testing of transgenic peanut lines with enhanced resistance to *Aspergillus* species
T.A. Coffelt	ARS-Suffolk	Maximize peanut production efficiency with improved germplasm and disease management strategies
R.J. Cole	ARS-Dawson	Breeding peanuts for aflatoxin resistance
D.W. Gorbet	AREC	Genetic improvement of peanuts (*Arachis hypogaea* L.)
K.W. Hilu	VPI&SU	A study of genetic diversity in peanuts using chloroplast and RRNA molecular markers
C.C. Holbrook	ARS-Tifton and UAY	Improvement of selection efficiency and peanut germplasm enhancement Development of improved peanut germplasm with resistance to disease and nematode pests
C.C. Holbrook M.E. Matheron	ARS-Tifton and UAY	Identification of peanut germplasm with resistance to aflatoxin
D.C. Hsi	NMSULL	Breeding valencia peanuts for blackhull resistance, high yield, and good quality Improving disease resistance, yield and quality in valencia peanuts
T.G. Isleib	NCSU	Peanut breeding and genetics
P.B. Johnsen K.L. Crippen	SRCC	Sensory evaluation of genetic lines of peanuts
J.S. Kirby J.R. Sholar	OSU	Plant germplasm introduction, increase, evaluation, documentation, maintenance and distribution
D.A. Knauft J.A. Knauft	UFG	Genetic improvement of peanut
H.A. Melouk D.L. Ketring	ARS-Stillwater	Evaluation of peanut germplasm for improved tolerance to biological and environmental stress
R.W. Mozingo	VPI&SU	Variety and quality evaluation of virginia-type peanut
R.E. Pettit O.D. Smith R.D. Waniska	TA&MU	Screening peanut genotypes for resistance to kernel invading and mycotoxin producing fungi
G.C. Phillips J.R. Barrow	NMSULC	Cellular and molecular genetics in crop improvement
R.N. Pittman	ARS-Griffin	Peanut germplasm - introduction, maintenance, distribution, and evaluation
D.G. Schilling D.A. Knauft	UFG	Development of methods for the selection of weed resistance characteristics in peanut
C.E. Simpson	TA&MU	Cross-compatibility, cytology and enhancement of *Arachis* germplasm Utilization of germplasm to improve peanut (*Arachis hypogaea* L.) cultivars
C.E. Simpson R. Pittman	TA&MU	Evaluation of the wild peanut (*Arachis* spp) germplasm collection
O.D. Smith C.E. Simpson D.H. Smith	TA&MU	Disease resistant peanut varieties for semi-arid environments Genetic improvement of peanut to alleviate production constraints and enhanced produce quality
H.T. Stalker	NCSU	Breeding aflatoxin resistant peanuts Utilization of species of *Arachis* to improve peanuts
F. Vazquez	ARS-Mayaguez	Study of peanut and maintenance of winter nursery in Puerto Rico
D.E. Williams	ARS-NY	Plant exploration in Bolivia to collect *Arachis* germplasm for crop improvement
B.R. Wiseman R.E. Lynch	ARS-Tifton	Plant resistance and germplasm enhancement for insect pests of southern crop

1. CPES = Coastal Plain Experiment Station, Tifton, Georgia; SRCC = Southern Regional Research Center, New Orleans, Louisiana; NCSU = North Carolina State University, Raleigh, North Carolina; ARS-Suffolk = Agricultural Research Service, Suffolk, Virginia; ARS-Dawson = Agricultural Research Service, Dawson, Georgia; AREC = Agricultural Research and Education Center, Marianna, Florida; VPI&SU = Virginia Polytechnical Institute and State University, Blacksburg, Virginia; ARS-Tifton = Agricultural Research Service, Tifton, Georgia; UAY = University of Arizona, Yuma, Arizona; NMSULL = New Mexico State University, Los Lunas, New Mexico; OSU = Oklahoma State University, Stillwater, Oklahoma; UFG = University of Florida, Gainesville, Florida; ARS-Stillwater = Agricul-tural Research Service, Stillwater, Oklahoma; TA&MU = Texas Agricultural and Mechanical University, College Station, Texas; NMSULC = New Mexico State University, Las Cruces, New Mexico; ARS-Griffin = Agricultural Research Service, Griffin, Georgia; ARS-Mayaguez = Agricultural Research Service, Mayaguez, Puerto Rico; ARS-NY = Agricultural Research Service, New York Botanical Gardens, Bronx, New York.

located in North Carolina, Oklahoma, and Texas (Table 4). Much of the research has been concerned with the crossing relationships among the various species and with cultivated groundnuts. Pathways for the transfer of genetic material from the species to cultivated groundnuts have been established (Simpson 1991; Stalker and Moss 1987). The progress of research in this area has been reviewed recently (Wynne and Halward 1989b; Stalker and Moss 1987) and is also the subject of a review paper in these Proceedings (see Stalker, pp. 281-295).

Cultivar development. Cultivar development programs at state experiment stations in Florida, Georgia, Oklahoma, North Carolina, Texas, and Virginia and at a private company (formerly Gold Kist; now Agratech) released numerous cultivars from 1980 until the present. These have broadened the genetic base of the groundnut crop in the USA and provided sources of pest resistance (Knauft and Gorbet 1989). Knauft and Gorbet assessed the genetic diversity among cultivars released by 1988 and concluded that the genetic base had been broadened considerably since 1976. Additional cultivar releases (Table 5) since this report have continued to broaden the genetic base (Isleib and Wynne 1992).

Cultivars released for their pest resistance since 1980 include NC 8C and NC 10C, with cylindrocladium black rot (*Cylindrocladium crotalariae*) resistance; Va 81B, with sclerotinia blight (*Sclerotinia minor*) resistance; and Southern Runner, with late leaf spot (*Cercosporidium personatum*) resistance. The cultivars that have been released primarily for their pest resistance have compromised one or more agronomic traits, making the cultivars less competitive in absence of the disease.

Considerable effort to develop pest-resistant groundnut cultivars began during the 1980s in the USA. Wynne et al. (1991) summarized progress in breeding for disease resistance. They concluded that although several U.S. breeding programs had initiated programs for resistance to diseases – *Aspergillus* spp (aflatoxin), tomato spotted wilt virus, nematodes, early and late leaf spots, sclerotinia blight, and cylindrocladium black rot – few cultivars have been released due to the short duration of the efforts. Because many sources of disease resistance have been identified by screening programs during the 1980s,

Table 5. Groundnut cultivar releases in the USA from 1980-1990.

Cultivar	Year released	Releasing agency
Runner Market Types		
Sunbelt Runner	1982	Georgia Agricultural Experiment Station and United States Department of Agriculture
Sunrunner	1983	Florida Agricultural Experiment Station
GK 7	1984	Gold Kist Inc.
Langley	1986	Texas Agricultural Experiment Station
OKrun	1986	Oklahoma Agricultural Experiment Station
Southern Runner	1986	Florida Agricultural Experiment Station
Tamrun 88	1988	Texas Agricultural Experiment Station
Georgia Runner	1990	Georgia Agricultural Experiment Station
MARCI	1990	Florida Agricultural Experiment Station
Virginia Market Types		
Va 81B	1981	Virginia Agricultural Experiment Station and United States Department of Agriculture
NC 8C	1982	North Carolina Agricultural Research Service
NC 9	1985	North Carolina Agricultural Research Service
NC 10C	1988	North Carolina Agricultural Research Service
NC-V 11	1989	North Carolina Agricultural Research Service, Virginia Agricultural Experiment Station, and United States Department of Agriculture
Spanish Market Types		
Pronto	1980	United States Department of Agriculture, Oklahoma Agricultural Experiment Station, and Georgia Agricultural Experiment Station
Spanco	1981	United States Department of Agriculture and Oklahoma Agricultural Experiment Station

much progress in breeding for disease resistance can be expected in the future. Breeding for disease resistance is now a priority in most U.S. breeding programs.

Much effort in the USA has also been devoted to the use of wild species of *Arachis* for sources of resistance to pests of groundnuts. Programs to transfer the high levels of resistance or immunity to early and late leaf spots, rust, nematodes, and viruses have been active during the 1980s (Stalker and Moss 1987; Wynne and Halward 1989b).

Recently the groundnut industry has identified quality and aflatoxin resistance as two major issues that needed additional research. These two issues were considered of highest priority because of the effect they have on export of groundnuts from the USA. Substantial funding from the National Peanut Foundation and the USDA has increased conventional breeding and molecular genetic research to address these problems.

Molecular genetics. Several researchers in the USA are now investigating and developing methodologies to use molecular techniques for improvement of groundnut. The use of restriction fragment length polymorphisms (RFLP) as molecular markers is being investigated by University of Georgia researchers (Kochert and Branch 1990) in cooperation with several other researchers. Little variation has been reported among cultivars, but abundant polymorphisms have been found among the diploid species of *Arachis*. Similar results were found for isozymes (Grieshammer and Wynne 1990; Stalker et al. 1990).

Several U.S. researchers are investigating somatic embryogenesis and plant regeneration in groundnuts. At least two laboratories have developed a repetitive somatic embryogenesis system and have established plants in soil (Durham et al. 1991; A.K. Weissinger, North Carolina State University, personal communication, 1991). These successes should expedite the use of gene transfer systems in the crop. The use of microprojectile bombardment as part of a gene transfer system in groundnut is being evaluated in at least two U.S. laboratories. The success of these systems, which appears to be imminent, will allow the movement of agronomically important genes into the groundnut.

Several laboratories are identifying and sequencing genes from viruses and from other plants that may be useful in improving the groundnut. This research is receiving funding support from the Peanut CRSP, private companies, the USDA, and state experiment stations.

Groundnut pests

Pesticides contributed about 45% of the variable cost for producing a hectare of groundnuts in North Carolina in 1991 (Table 3). These costs, which are similar to those in other groundnut-producing states, have continued to increase in spite of an emphasis on reduction of chemicals by means of an integrated pest management (IPM) approach to lower production costs during the last decade. Scientists at chemical companies in conjunction with researchers at public institutions and private consultants working on a contract basis have continued to develop and screen new chemical compounds for weed, disease, and insect control. These chemicals, although costly, continue to provide the primary means for pest control in groundnuts because the growers are producing a high income crop.

Weeds. Groundnut scientists now stress weed management rather than weed control (Table 6). Research has shown that a successful weed management program consists of weed control in rotational crops, cultivation, if needed, and proper selection and use of herbicides (York 1991). Although not yet adopted by growers, researchers have developed an integrated approach to weed management with herbicide recommendations based on weed populations that are determined by scouting fields for the weed species present and the general level of infestation. Threshold damage levels are being determined for each weed species and application of a herbicide is based on a specific need (Linker and Coble 1990).

Even though growers continue to use herbicides before sowing, researchers are now working to develop herbicide programs that are postemergence and based on need. This approach is cheaper and more environmentally sound. It is made possible through the development of herbicides that produce excellent results when applied after sowing. These new chemicals are very specific and may be used in small amounts. They will allow growers to control weeds with minute amounts of active ingredient, reducing residues and adverse impact on the environment.

While weed control in groundnuts has improved with the development of new herbicides, their widespread use has produced changes in weed populations. Research during the 1980s demonstrated that the reduction of the population of one weed in an area will result in another weed species significantly increasing to fill the void. Rotation of herbicides and crops are important management strategies to reduce populations of new problem weed species. The

Table 6. U.S. groundnut projects involving weed management.

Investigator(s)	Location[1]	Title
D.C. Bridges A.E. Smith J.W. Wilcut	UGG	Phenology, population dynamics, and interference: A basis for understanding weed biology and ecology
H.D. Coble	NCSU	Weed management systems for field crops
W.C. Johnson	ARS-Tifton	Weed biology, ecology, and management systems for peanuts and rotation crops in the Southeastern Coastal Plains
		Weed management systems for peanuts and rotation crops in the Coastal Plains
W.C. Johnson, III	CPES	Weed ecology and control in peanuts and rotation crops
		Weed management, ecology, and multipest interactions in peanuts and systems that include peanuts
G.R. Wehtje	AUA	Herbicidal weed control in peanuts
J.W. Wilcut	VPI&SU	Ecology and economic control of weeds in peanut
A.C. York	NCSU	Weed management systems for agronomic crops

1. UGG = University of Georgia, Griffin, Georgia; AUA = Auburn University, Auburn, Alabama; see Table 4 for other abbreviations.

grower must consider whether to use a herbicide, choose the appropriate herbicide, and consider its possible environmental impact. Because weed management decisions are becoming more complicated, recent research has concentrated on developing computer-assisted decision models. Models such as HERB are now being adapted to groundnuts (H.D. Coble, North Carolina State University, personal communication, 1991).

Research on weed biology, development of new herbicides, and a change in philosophy of use will soon influence the practices to manage weeds used by groundnut farmers in the USA.

Diseases. In the USA, diseases of groundnut receive the greatest research emphasis of the three major groups of pests, as evidenced by the 36 CSRS projects on diseases and nematodes (Table 7).

Research in the USA has primarily been concentrated on a group of diseases that cause or have potential to cause large economic loss. These diseases include early leaf spot (*Cercospora arachidicola*), late leaf spot (*Cercosporidium personatum*), southern stem rot (*Sclerotium rolfsii*), cylindrocladium black rot (*Cylindrocladium crotalariae*), sclerotinia blight (*Sclerotinia minor*), pythium pod rot (*Pythium myriotylum*), rhizoctonia limb rot (*Rhizoctonia solani*), bud necrosis (tomato spotted wilt virus), peanut stripe virus, two nematodes (*Pratylenchus brachyurus* and *Meloidogyne arenaria*), and the toxin-producing fungi (*Aspergillus parasiticus* and *A. flavus*).

Resistant cultivars and a long rotation of groundnuts with other crops have long been recognized as two of the best disease management tools available. However, as resistant cultivars have not been developed for many important groundnut diseases and long-term rotations are often not possible, cultural practices and chemical controls are most often used to control diseases in the USA (Bailey 1991).

Several research projects have developed strategies to reduce the amount of chemicals used in disease control. Using information from studies on the effect of weather on leaf spot development and the threshold level of disease, leaf spot advisory systems have been established in several states to alert growers when environmental factors favor infection of the crop. Advisories reduce the number of applications of chemical needed to control leaf spots.

During the past decade, plant pathologists in the USA have investigated the biology of pathogens and the effects of climatic factors on disease development. This research, which was recently summarized by Wynne et al. (1991), is directed toward development of management strategies for disease control and toward development of resistant cultivars.

Insects. Until the last decade, much entomological research in the USA was concerned with efficacy of control methods, especially the use of chemicals. During the last decade, emphasis in research has shifted to understanding the life cycle of the pest and how the insect interacts with biotic and abiotic components of the ecosystem (Table 8). Another recent shift is to research that emphasizes an IPM approach to insect control. Studies to define threshold levels have been conducted in order to reduce pesticide use.

Table 7. Groundnut projects including groundnut diseases compiled from USDA-CRIS.

Investigator(s)	Location[1]	Title
P.A. Backman A.K. Hagan W.S. Gazaway	AUA	Management of peanut and soybean diseases using chemical, biological, or cultural methods
J.E. Bailey	NCSU	Peanut disease management
D.K. Bell	CPES	Alternate methods of disease control in peanut
R.D. Berger	UFG	Biological control and dynamical models of species interactions
M.K. Beute	NCSU	Biology and control of peanut diseases
K.L. Bowen	AUA	Epidemiology and ecology of aflatoxin-producing fungi and rhizosphere-inhabiting organisms in peanut
	ARS-Dawson	Interactive effects of lesser cornstalk borers, *Aspergillus* incidence and aflatoxin in peanuts
T.B. Brenneman	CPES	Improving foliar disease management of peanut and pecan
		Management of southern stem rot and rhizoctonia limb rot of peanut
R.J. Cole	ARS-Dawson	Environmental and biochemical factors responsible for preharvest aflatoxin resistance in peanuts
A.K. Culbreath	CPES	Epidemiology and management of foliar diseases of peanut
J.W. Demski	UGG	Peanut viruses: etiology, epidemiology, and nature of resistance
J.W. Demski C.W. Kuhn	GAES	Peanut viruses: etiology, epidemiology, and nature of resistance
D.W. Dickson R.A. Dunn	UFG	Biology and management of nematodes affecting agronomic crops
J.W. Dorner	ARS-Dawson	Biochemical, environmental and microbiology resistance for preharvest aflatoxin resistance
A.B. Filonow	OSU	Management of peanut pod rot in Oklahoma with emphasis on the role of *Pythium* sp
D.R. Fravel G.C. Papavizas	ARS-Beltsville	Biocontrol and integrated control of seedling diseases and wilts of major crops
W.J. Grichar	TA&MUY	Etiology, epidemiology, and management of peanut diseases
R.T. Gudauskas	AUA	Identification and control of plant viruses in Alabama
R.A. Kinloch	FARECJ	Biology and management of nematodes affecting agronomic crops
T.A. Kucharek F.M. Shokes	UFG	Management of diseases of field crops in north Florida
J.A. Lewis G.C. Papavizas	ARS-Beltsville	MD pilot testing of gliocladium virens formulations *Sclerotium rolfsii*
H.A. Melouk D.L. Ketring J.L. Sherwood	OSU	Epidemiology and control of *Sclerotinia* blight in peanut
N.A. Minton	ARS-Tifton	Nematode management strategies to reduce nematicide use on agronomic crops of the Southeast
		Nematode pathology and management in agronomic crops of the Southeastern Coastal Plain
	CPES	Improving nematode management in agronomic crops
F.L. Mitchell J.W. Smith, Jr.	TA&MU	Transmission efficiency of thrips vectors of tomato spotted wilt virus
F.L. Mitchell J.W. Smith, Jr. D.H. Smith	TA&MU	An epidemiological model of tomato spotted wilt virus on southern crops
F.W. Nutter	UGA	Analysis of epidemiological components that reduce the rate of plant disease epidemics
P.M. Phipps	TREC	Improved strategies for disease management in peanuts
P.M. Phipps D.M. Porter	VPI&SU	Management of rhizosphere dynamics to control soilborne pathogens and promote plant productivity
D.M. Porter	ARS-Blacksburg	Biological control of *Sclerotium rolfsii* of peanut with the mycoparasite, gliocladium virens

Continued

Table 7. *Continued*

Investigator(s)	Location[1]	Title
J.F. Robens	ARS-Beltsville	Preharvest control of aflatoxin
M.B. Sheikh R.J. Cole	FA&MU	Purification and properties of stilbene synthetase from peanut kernels
J.L. Sherwood	OSU	Biology and control of plant viruses in Oklahoma
F.M. Shokes T.A. Kucharek	UFG	Management of diseases of field crops in north Florida
H.W. Spurr	ARS-Oxford	Biological control of leaf spot disease

1. AUA = Auburn University, Aurburn, Alabama; UGG = University of Georgia, Griffin, Georgia; GAES = Georgia Agricultural Experiment Station, Griffin, Georgia; ARS-Beltsville = Agricultural Research Service, Beltsville, Maryland; TA&MUY = Texas Agricultural and Mechanical University, Yoakum, Texas; FARECJ = Florida Agricultural and Educational Center, Jay, Florida; UGA = University of Georgia, Athens, Georgia; TREC = Tidewater Research and Education Center, Suffolk, Virginia; ARS-Blacksburg = Agricultural Research Service, Blacksburg, Virginia; FA&MU = Florida Agricultural and Mechanical University, Tallahassee, Florida; ARS-Oxford = Agricultural Research Service, Oxford, North Carolina; for other abbreviations see Table 4.

Table 8. Projects on groundnut entomology compiled from USDA-CRIS.

Investigator(s)	Location[1]	Title
M.E. Barbercheck	NCSU	Soil insect biology, ecology and management
D.G. Boucias	UFG	Pathology and efficacy of *Beuveria bassiana* against lesser cornstalk borer
R.L. Brandenburg	NCSU	Management of arthropods of peanuts
T.P. Mack	AUA	Biology and management of peanut insects, with emphasis on the lesser cornstalk borer
W.W. McMillian B.R. Wiseman R.E. Lynch	ARS-Tifton	Plant resistance and germplasm enhancement for insect pests of southern crops
J.W. Smith, Jr. F.L. Forrest	TA&MU	Biological and integrated management of peanut insect pests
F.C. Tingle J.R. McLaughlin E.R. Mitchell	ARS-Gainesville	Behavioral ecology and population dynamics of crop insects and their parasitoids
J.W. Todd	CPES	Arthropod pest management in peanuts
J.W. Todd T. Brenneman W.D. Branch	CPES	Biotic and abiotic stresses involving arthropods on peanut: evaluation and management
J.R. Weeks	AUA	Population biology and management of thrips and other arthropod pests of peanuts

1. AUA = Auburn University, Auburn, Alabama; ARS-Tifton = Agricultural Research Service, Tifton, Georgia; ARS-Gainesville = Agricultural Research Service, Gainesville, Florida; for other abbreviations see Table 4.

This information has been used to establish an IPM system for groundnuts.

Considerable effort by entomologists in the USA has been expended to identify germplasm that is resistant to insect pests. Emphasis on this area has decreased in the USA with the retirement of W.V. Campbell at North Carolina State University.

Cultural and management practices

In addition to the weed management projects, there are more than a dozen research projects concerned with cultural and management practices of groundnuts in the USA (Table 9). As new groundnut cultivars are released, research is often conducted to

Table 9. Groundnut projects involving management and cultural practices compiled from USDA-CRIS.

Investigator(s)	Location[1]	Title
J.F. Adams	AUA	Soil acidity factors that affect crop production in Alabama
F.J. Adamsen D.M. Porter F.S. Wright	ARS-Suffolk	Peanut production efficiency improved through tillage systems, soil and water management and pest control
J.L. Butler E.J. Williams J.M. Troeger	ARS-Tifton	Develop peanut production and processing management systems in the Southeast
C.L. Butts J.I. Davidson	ARS-Dawson	Technology transfer of expert system peanut
E. Cooter	UON	Meteorological research and agricultural management modeling for southern agriculture
R. Elliot	OSU	Meteorological research and agricultural management modeling for southern agriculture
G.J. Gascho	CPES	Calcium related nutrition of peanut
D. Hartzog J.F. Adams	AUA	Effects of soil fertility on peanut yield and grade
G. Hoogenboom	UGA	Meteorological research and agricultural management modeling for southern agriculture
T.P. Mack P.A. Mackman R. Rodriguez-Kabana	AUA	Development of microcomputer-based peanut pest management system
R.W. McClendon	UGA	Decision support systems for crop production
N.L. Powell	VPI&SU	Movement of water and chemicals applied to corn and peanut using subsurface micro-irrigation
C.W. Swann	TAES	Improving management strategies for increased yield, quality and profitability of peanut

1. AUA = Auburn University, Auburn, Alabama; UON = University of Oklahoma, Norman, Oklahoma; UGA = University of Georgia, Athens, Georgia; TAES = Tidewater Agricultural Experiment Station, Suffolk, Virginia; for other abbreviations see Table 4.

determine critical levels of calcium, phosphorus, and potassium required for high yield and quality of both the commercial crop and of seed. In addition, research has been and continues to be conducted on sowing patterns (twin vs single row, plant population) as new cultivars are released.

Conservation tillage systems maximizing the efficient use of low quality supplemental water high in sodium applied through a deep buried subsurface trickle irrigation system have been investigated for virginia-type groundnuts (Adamsen 1990). Yields in the conservation tillage system have been 2–8% lower than the conventional yields when high rates of gypsum are applied to the groundnuts grown under the conservation tillage system.

Because of an emphasis on quality and aflatoxin control in the Southeast (Georgia, Alabama, Florida) and the occurrence of several growing seasons with poor rainfall, considerable management research has been conducted on the timing and efficient use of irrigation. Early season irrigation has been shown to be important in order to maintain adequate subsoil moisture at fruiting which occurs from 60–110 days after sowing.

Much of the management research on groundnuts in the USA during the last decade has involved the use of computers to assist in making management decisions (Table 9).

Plant physiology

Several scientists conduct research on the physiology of groundnut in the USA (Table 10). However, most of these scientists are not devoted exclusively to groundnut but work on several crops. During the last decade, computer models of plant growth and development have received attention from several researchers. Emphasis has also been placed on environmental and genotypic control of assimilate allocation. Studies have demonstrated that high-yielding culti-

Table 10. Groundnut plant physiology projects compiled from USDA-CRIS.

Investigator(s)	Location[1]	Title
K.J. Boote J.M. Bennett C.K. Hiebsch	UFG	Environmental and genotypic control of assimilate allocation in crops
J.S. Calahan	TAESS	The effects of NaCl and $CaCl_2$ salinity on nodulation of peanuts
G.H. Elkan	NCSU	Nitrogen fixation and the regulation of product formation by *Bradyrhizobium* spp (*Arachis*)
C.D. Foy R.K. Howell A.L. Fleming	ARS-Beltsville	Response mechanism of plants to drought and mineral stresses
L.C. Hammond	UFG	Environmental and genotypic control of assimilate allocation in crops
C.K. Hiebsch	UFG	Ecological responses of crop plants to the environment in a systems management approach
A.E. Hiltbold D.L. Thurlow	AUA	Overcoming factors limiting biological nitrogen fixation by leguminous plants
J.E. Hook E.D. Threadgill G. Vellidis	CPES	Simulation of crop root response to soil water and soil strength
R.K. Howell	ARS-Beltsville	Selection of stress resistant *Rhizobium* and legume gene sources to increase N_2-fixation
C.S. Kvien	CPES	Improve seed maturity and reduce chemical residue in peanut Physiology of peanut growth and development
H.E. Pattee	NCSU	Chemistry and morphology peanut germplasm in relation to assimilate metabolism and flavor quality
R.P. Patterson	NCSU	Physiological processes leading to drought resistance in soybean and peanut
A.M. Schubert	TA&MU	Physiological factors in peanut productivity and production
M.B. Sheikh	FA&MU	Effect of genetic, agronomical and environmental factors on peanut seed quality
I.D. Teare J.E. Funderburk F.M. Shokes	NFREC	Crop physiological basis for biological pest control and systems management
R. Wells	NCSU	Genotypic and environmental factors related to productivity of soybeans and peanuts
A.G. Wollum	NCSU	Enhancing beneficial microorganisms in the rhizosphere Enhancing biological nitrogen fixation using superior *Bradyrhizobium* spp and modifying rhyzospheres Overcoming factors limiting biological nitrogen fixation by leguminous plants

1. TAESS = Texas Agricultural Experiment Station, Stephenville, Texas; ARS-Beltsville = Agricultural Research Service, Beltsville, Maryland; AUA = Auburn University, Auburn, Alabama; FA&MU = Florida Agricultural and Mechanical University, Tallahassee, Florida; NFREC = Northern Florida Research and Education Center, Quincy, Florida; for other abbreviations see Table 4.

vars partition more assimilate to the fruits (Bi et al. 1989). Breeding has increased the fruit-to-plant ratio and has resulted in higher yields.

Considerable attention has been given to the selection of *Bradyrhizobium* strains and their influence on yield and product formation during the last decade. Superior bradyrhizobial strains have been identified and have been utilized commercially (Elkan et al. 1980; Phillips et al. 1989). *Bradyrhizobium* strains have been demonstrated to alter sugars, fatty acids, and amino acid composition of groundnut seeds (G.H. Elkan, North Carolina State University, personal communication, 1990).

Projects in at least four states are giving priority to determining the effect of drought on growth and development. Studies are designed to identify physiological, developmental, and morphological traits related to efficient groundnut plants.

Flavor, quality, postharvest handling, and processing

Factors affecting flavor and quality. The factors affecting groundnut quality and flavor and the measurement of flavor and quality have received priority especially by USDA scientists located at state experiment stations and at USDA regional laboratories (Table 11). The biochemical changes related to good peanut flavor as measured by sensory evaluation have been investigated in many laboratories. Volatile flavor profiles and factors related to off-flavors have been established (Sanders et al. 1989; Pattee et al. 1989, 1990; Young and Hovis 1990). However, reliable objective methods for measuring good peanut flavors are still under investigation. The chemical reactions involved in flavor stability have been well documented. Because of this research on fatty acid composition, selection of cultivars high in oleic acid and proper storage and handling have been emphasized.

Table 11. Postharvest groundnut projects involving flavor and quality compiled from USDA-CRIS.

Investigator(s)	Location[1]	Title
S.S. Chang Chi-Tang Ho	RUB	New chemical reactions involved in flavor and flavor stability of edible fats and oils
B.L. Clary D.L. Ketring	OSU	Effect of windrow shading during field curing on peanut quality
K.L. Crippen T.D. Drumm L. Munchausen	SRRC	Origin of off-flavors in peanuts
K.L. Crippen N.V. Lovegren J.R. Vercellotti	SRRC	New Comparative quality of U.S. and foreign origin peanuts
J.E. Davidson T.H. Sanders R.J. Cole	NPF	Development of technology for peanut quality enhancement
J.A. Lansden T.H. Sanders	ARS-Dawson	Growth physiology and quality/flavor development in peanuts
D.J. Parrish	VPI&SU	Lipid antioxidants and aging in oily seeds
H.E. Pattee	ARS-Raleigh	Evaluation of peanut quality at buying station points by use of the alcohol meter
J. Pominski M.K. Chang R.S. Kadan	SRRC	New engineered foods from nonfat dry milk, vegetable proteins and other agricultural commodities
A.V.A. Ressureccion L.R. Beuchat R.E. Brackett	UGG	Processes for development and utilization of peanut products
M.B. Sheikh T.H. Sanders	FA&MU	Growth environment, maturity and curing of peanuts as related to precursors of roast flavor
J.A. Singleton	ARS-Raleigh	Quality changes in freeze-damaged peanuts
J.A. Singleton H.E. Pattee	ARS-Raleigh	Chemistry and morphology of peanut germplasm in relation to assimilate metabolism and flavor quality
S.L. Taylor J.H. Rupnow	UNL	Food allergies and sensitivities
T.B. Whitaker	ARS-Raleigh	Measurement and preservation of peanut quality during marketing, handling, and storage
C.T. Young	NCSU	Sensory and compositional factors of peanuts, treenuts, and their products
J.J. Young C.F. Abrams	NCSU	Integrated systems and controls for processing and storing agricultural commodities

1. RUB = Rutgers University, Brunswick, New Jersey; NPF = National Peanut Foundation, Alexandria, Virginia; UGG = University of Georgia, Griffin, Georgia; FA&MU = Florida Agricultural and Mechanical University, Tallahassee, Florida; ARS-Raleigh = Agricultural Research Service, Raleigh, North Carolina; UNL = University of Nebraska, Lincoln, Nebraska; for other abbreviations see Table 4.

Quality changes caused by freeze damage in the Virginia–Carolina production area have been determined (Singleton and Pattee 1989). Measurement of off-flavors at buying stations using an alcohol meter is being pursued at present (H.E. Pattee, North Carolina State University, personal communication, 1990).

Several scientists have been working to develop equipment and procedures to preserve groundnut quality during handling and storage (Table 12). The largest of these projects was supported by the National Peanut Council and involved the installation of belt cleaning machines at eight buying stations across the groundnut production area. These machines were successful in reducing foreign material, immature seeds, and the risk of aflatoxin contamination in farmers' stock groundnuts. However, the economic

Table 12. Postharvest groundnut projects involving harvest, curing, and processing compiled from USDA-CRIS.

Investigator(s)	Location[1]	Title
F.H. Arthur	ARS-Savannah	Evaluate and assess pesticide chemicals for disinfestation of commodities, storage, processing and transportation facilities
F.H. Arthur R.E. Bry	ARS-Savannah	Evaluate and assess pesticide chemicals for disinfestation of commodities storage, processing and transportation facilities
P.D. Blakenship C. Butts R.N. Shulstad	ARS-Dawson	Develop methodology and systems for increasing the productivity and quality of peanuts
M.K. Chang J. Pominski P.J. Wan	SRRC	New engineered foods from nonfat dry milk, vegetable proteins and other agricultural commodities
J.S. Cundiff	VPI&SU	Integrated systems and controls for processing and storage agricultural commodities
G.A. Kranzler F.E. Dowell	OSU	Peanut kernel damage detection using machine vision
Y.C. Hung	GAES	Textural and microstructural changes in food during postharvest handling, processing, and storage
D. Kincannon C.L. Butts J.S. Smith, Jr.	ARS-Dawson	Determination of shrinkage factors in stored farmers stock peanuts
B.D. McLendon	UGA	Integrated systems and controls for processing and storing agricultural commodities
R.D. Phillips	UGG	Effects of storage and processing on protein and starch digestibility in cereals and legumes
J. Pominski	SRRC	New manufacturing partially defatted peanuts
T.H. Sanders J.I. Davidson J.W. Dorner	ARS-Dawson	Automated objective system for grading farmers stock and shelled peanuts
C.R. Santeree	UGA	Pecan and peanut quality improvement and pesticide removal during postharvest processing
B.P. Verma M.S. Chinnan E.W. Tollner	UGG	Physical properties of peanut for processing alternatives
T.B. Whitaker	NCSU	Measurement and preservation of peanut quality during marketing handling and storage
F.S. Wright S. Cundiff D.M. Porter	VPI&SU	Effect of production, harvesting, and curing variable on J. peanut quality

1. ARS-Savannah = Agricultural Research Service, Savannah, Georgia; GAES = Georgia Agricultural Experiment Station, Griffin, Georgia; UGA = University of Georgia, Athens, Georgia; UGG = University of Georgia, Griffin, Georgia; for other abbreviations see Table 4.

cost-benefit ratio has been marginal (Blankenship 1990).

Research on aflatoxin contamination has become the foremost priority of the groundnut industry in the USA. There are several projects devoted exclusively to developing and adopting methods for identifying aflatoxin-contaminated lots of groundnuts at the buying point. In addition to these projects (Table 13), several projects have one or more objectives that address aflatoxin contamination. Screening of groundnut germplasm for resistance, evaluation of identified resistance, molecular techniques, the role of the environment and prevention of infection by irrigation, and proper storage and handling are all being investigated as means of reducing contamination. If these methods fail, research to identify contaminated lots and decontaminate these lots is being pursued. The U.S. industry has a goal of reducing the level of aflatoxin in edible groundnut products by the year 2000.

Curing and processing. Research involving nuclear magnetic resonance (NMR) for sizing, separating, and sorting groundnuts has been investigated since the early 1970s. Groundnut seed with low densities have been associated with high levels of aflatoxin (Kirksey et al. 1989). Researchers at the USDA laboratory in Dawson, Georgia are developing an automated objective system for grading farmers' stock and shelled peanuts (Table 12). The system is designed to improve grading accuracy and ensure quality of U.S. groundnuts. Related research is being performed by USDA scientists stationed at North Carolina State University. Several researchers continue to develop a computerized curing system that utilizes solar-assisted partial air recirculation for drying (Table 13).

Marketing. Economic models that include formula price model for farmers' stock groundnuts, supply and demand, and price prediction models are being tested to relate variables that affect demand and prices to the demand and price of groundnuts (Table 14).

Research in Other Countries of North America

Groundnut research in Canada has focused on the problems inherent in growing a crop in an area where it has not previously been grown commercially (Ablett et al. 1981). The area of concern is limited to a region along the northern shore of Lake Erie in Ontario, Canada, at approximately 43°N with a mean temperature of 18.2°C during a 130–day growing season (Michaels 1988). Research was initiated in 1970 at Delhi, Ontario. Production practices used in the USA were adapted for the new growing area. High

Table 13. Postharvest groundnut projects involving aflatoxin compiled from USDA-CRIS.

Investigator(s)	Location[1]	Title
C.W. Bacon J.K. Porter K. Nishie	ARS-Athens	Evaluate the hazards of mycotoxins produced by resistance to pathogens in introduced plant germplasm
F. Bodiford F.E. Dowell	GFSIS	Chemical detection of aflatoxin in farmers stock peanuts sample size study
A.G. Gillaspie, Jr.	ARS-Griffin	Detection and elimination of/and sources of resistance to pathogens in introduced plant germplasm
W.M. Hagler, Jr. F.E. Dowell	NCSU	Detection of aflatoxin in farmers stock peanuts by chemical means
M.A. Harrison	UGA	Mycotoxin distribution and control in foods and food processing facilities
R.E. Pettit R.A. Taber	TA&MU	Mycotoxin management in peanuts by prevention of contamination and monitoring
T. Whitaker F.E. Dowell	ARS-Dawson	Chemical detection of aflatoxin in farmers stock peanuts sample size study
D.M. Wilson	CPES	Aflatoxins in peanuts

1. ARS-Athens = Agricultural Research Service, Athens, Georgia; GFSIS = Georgia Federal and State Inspection Service, Albany, Georgia; UGA = University of Georgia, Athens, Georgia; for other abbreviations see Table 4.

Table 14. Postharvest groundnut projects involving economics compiled from USDA-CRIS.

Investigator(s)	Location[1]	Title
J.R. Allison V.H. Calvert R.B. Moss	UGG	Economic analysis of selected production practices, enterprises, and farming systems at Georgia
B.A. Babcock	NCSU	Effects of government programs on the management decisions of tobacco and peanut producers
B.R. Miller M.D. Lamb R.N. Shulstad	UGA	Develop marketing models for peanuts

1. UGG = University of Georgia, Griffin, Georgia; UGA = University of Georgia, Athens, Georgia; for other abbreviation see Table 4.

plant populations of spanish or valencia cultivars were found to give yields equivalent to yields of the same cultivars in the USA (Roy et al. 1980). The objective of present research is to develop cultivars that are adapted for the short growing season (Michaels 1988).

Groundnut research is also being conducted in Chapingo, Mexico, at the Universidad Autonoma Chapingo y Colegio de Postgraduados, although we have been unable to obtain a complete description of the program there. Research on genetics and cultivar evaluation has been conducted there for several years.

References

Ablett, G.R., Roy, R.C., and **Tanner, J.W.** 1981. Agronomic aspects of normal and abnormal root formation in peanuts (*Arachis hypogaea* L.). Peanut Science 8:25–30.

Adamsen, F.J. 1990. The influence of irrigation water quality and irrigation method on the mineral composition of peanut tissue. Proceedings of American Peanut Research and Education Society 22:63. (Abstract.)

Babcock, B.A. 1990. Situation and outlook. Pages 1–3 *in* 1990 peanuts. Publication AG-331. Raleigh, North Carolina, USA: North Carolina Agricultural Extension Service.

Bailey, J.E. 1991. Peanut disease control. Pages 82-96 *in* 1990 peanuts. Publication AG-331. Raleigh, North Carolina, USA: North Carolina Agricultural Extension Service.

Bi, T., Wells, R., and **Wynne, J.C.** 1989. Response of peanut dry matter allocation to genetic selection for yield in North Carolina. Proceedings of American Peanut Research and Education Society 21:22. (Abstract.)

Blankenship, P.D. 1990. Effects on quality of screening farmers stock peanuts with greater than four percent loose shelled kernels. Proceedings of American Peanut Research and Education Society 22:74. (Abstract.)

Carley, D.H. 1983. Production and marketing of peanuts in the United States. Pages 19-40 *in* Peanuts: production, processing, products (Woodroof, J.G., ed.). Westport, Connecticut, USA: AVI Publishing Co.

Davidson, J.I., Jr., Whitaker, T.B., and **Dickens, J.W.** 1982. Grading, cleaning, storage, shelling and marketing of peanuts in the United States. Pages 571-623 *in* Peanut science and technology (Pattee, H.E., and Young, C.T., eds.). Yoakum, Texas, USA: American Peanut Research and Education Society.

Durham, R.E., Parrott, W.A., Baker, C.M., and **Wetzstein, H.Y.** 1991. Repetitive somatic embryogenesis and plant regeneration in peanut. Agronomy Abstracts 1991:194.

Elkan, G.H., Wynne, J.C., Schneeweis, T.J., and **Isleib, T.G.** 1980. Nodulation and nitrogenase activity of peanuts inoculated with single strain isolates of *Rhizobium*. Peanut Science 7:95-97.

Grieshammer, U., and **Wynne, J.C.** 1990. Isozyme variability in mature seeds of U.S. peanut cultivars and collections. Peanut Science 17:72-75.

Isleib, T.G., and **Wynne, J.C.** 1992. Use of plant introductions in peanut improvement. Pages 77-116 *in* Use of plant introductions in cultivar development (Shands, H.L., and Wiesner, L.E., eds.). Part 2. Special Publication 20. Madison, Wisconsin, USA: Crop Science Society of America.

Kirksey, J.W., Cole, R.J., and **Dorner, J.W.** 1989. Relationship between aflatoxin content and buoyancy of Florunner peanut kernels. Peanut Science 16:48-51.

Knauft, D.A., and **Gorbet, D.W.** 1989. Genetic diversity among peanut cultivars. Crop Science 29:1417-1422.

Knauft, D.A., Norden, A.J., and **Gorbet, D.W.** 1987. Peanut breeding. Pages 346-384 *in* Principles of cultivar development (Fehr, W.R., ed.). Vol. 2. New York, USA: Macmillan.

Kochert, G., and **Branch, W.D.** 1990. RFLP analysis of peanut cultivars and wild species. Proceedings of American Peanut Research and Education Society 22:53. (Abstract.)

Linker, H.M., and **Coble, H.D.** 1990. Effect of weed management strategy and sowing date on herbicide use in peanuts (*Arachis hypogaea*). Weed Technology 4:20-25.

Michaels, T.E. 1988. Effect of selection for emergence and maturity on yield of Ontario peanuts. Peanut Science 15:69-72.

Neuman, D.F. 1991. Situation and outlook. Pages 1-3 *in* 1991 Peanuts. Publication AG-331. Raleigh, North Carolina, USA: North Carolina Agricultural Extension Service.

Pattee, H.E., Rogister, E.W., and **Giesbrecht, F.G.** 1989. Interrelationships between headspace volatile concentration, selected seed-size categories and flavor in large-seeded virginia-type peanuts. Peanut Science 16:38-42.

Pattee, H.E., Yokoyama, W.H., Collins, M.F., and **Giesbrecht, F.G.** 1990. Interrelationships between headspace volatile concentration, marketing grades and flavor in runner-type peanuts. Journal of Agricultural and Food Chemistry 38:1055-1060.

Phillips, T.D., Wynne, J.C., Elkan, G.H., and **Schneeweis, T.J.** 1989. Field evaluations of peanut cultivar-*Bradyrhizobium* specificities. Peanut Science 16:54-57.

Roy, R.C., Tanner, J.W., Hatley, O.E., and **Elliott, J.M.** 1980. Agronomic aspects of peanut (*Arachis hypogaea* L.) production in Ontario. Canadian Journal of Plant Science 60:679-686.

Sanders, T.H., Vercellotti, J.R., Blankenship, P.D., Cuppen, K.L., and **Civille, G.C.** 1989. Interaction of maturity and curing temperature on descriptive flavor of peanuts. Journal of Food Science 54:1066-1069.

Simpson, C.E. 1983. Plant exploration: planning, organization and implementation with special emphasis on *Arachis*. Pages 1-20 *in* Conservation of crop germplasm: an international perspective (Brown, W.L., Chang, T.T., Goodman, M.M., and Jones, Q., eds.). Special Publication no. 8. Madison, Wisconsin, USA: Crop Science Society of America.

Simpson, C.E. 1990. Collecting wild *Arachis* in South America: past and future. Pages 10-17 *in* IBPGR International Crop Network Series 2. Report of a Workshop on the Genetic Resources of Wild *Arachis* Species, 29 Feb-2 Mar 1989, Cali, Colombia, including the preliminary descriptors for *Arachis* (IBPGR/ICRISAT). Rome, Italy: International Board for Plant Genetic Resources.

Simpson, C.E. 1991. Pathways for introgression of pest resistance into *Arachis hypogaea* L. Peanut Science 18:22-26.

Singleton, J.E., and **Pattee, H.E.** 1989. Effect of chilling injury on windrowed peanuts. Peanut Science 16:51-53.

Stalker, H.T., Jones, T.M., and **Murphy, J.P.** 1990. Isozyme variability among *Arachis* species. Proceedings of American Peanut Research and Education Society 22:50. (Abstract.)

Stalker, H.T., and **Moss, J.P.** 1987. Speciation, cytogenetics, and utilization of Arachis species. Advances in Agronomy 41:1-40.

USDA (U.S. Department of Agriculture). 1983-89. Agricultural Statistics. Washington, D.C., USA: U.S. Government Printing Office.

USDA (U.S. Department of Agriculture). 1990a. Oil Crops, Situation and Outlook Report OCS-25. Washington, D.C., USA: U.S. Government Printing Office.

USDA (U.S. Department of Agriculture). 1990b. Oil Crops, Situation and Outlook Report OCS-27. Washington, D.C., USA: U.S. Government Printing Office.

Woodroof, J.G. 1983. Historical background. Pages 1-18 *in* Peanuts: production, processing, products (Woodroof, J.G., ed.). Westport, Connecticut, USA: AVI Publishing Co.

Wynne, J.C., Beute, M.K., and **Nigam, S.N.** 1991. Breeding for disease resistance in peanut (*Arachis hypogaea* L.). Annual Reviews of Phytopathology 29:279-303.

Wynne, J.C., and **Halward, T.M.** 1989a. Germplasm enhancement in peanut. Pages 155-174 *in* Scientific management of germplasm: characterization, evaluation and enhancement (Stalker, H.T., and Chapman, C., eds.). Rome, Italy: International Board for Plant Genetic Resources.

Wynne, J.C., and **Halward, T.M.** 1989b. Cytogenetics and genetics of *Arachis*. Critical Reviews in Plant Science 8:189-220.

York, A. 1991. Weed management in peanuts. Pages 54-81 *in* 1991 Peanuts. Publication AG-331. Raleigh, North Carolina, USA: North Carolina Agricultural Extension Service.

Young, C.T., and **Hovis, A.R.** 1990. A method for rapid analysis of headspace volatiles of raw and roasted peanuts. Journal of Food Science 55:279-280.

Groundnut Production and Research in South America

I.J. Godoy[1] and E.H. Giandana[2]

Abstract

*The total commercial groundnut (*Arachis hypogaea*) production area in South America is currently about 350 000 ha. The largest areas cultivated are located in Argentina, in the province of Córdoba (180 000 ha), and Brazil, in the state of São Paulo (80 000 ha).*

*Groundnut production areas continued to decline between 1980 and 1990, as also happened between 1970 and 1980. The major cause for this was the considerable decrease in groundnut oil extraction, since industries gradually shifted to other more profitable oil sources, especially soybeans (*Glycine max*). However, the decline in total production was less pronounced as a consequence of higher crop yields. Average yields in the 1980s were nearly 50% higher than those of the 1970s.*

*The higher crop yields attained by Argentina and Brazil were attributed to the adoption of available technologies such as crop rotation, chemical control of weeds, insects, and diseases, and improved harvesting practices. In Argentina the replacement of the valencia and spanish cultivars by virginia runner cultivars also played an important role. In Brazil yield increases can also be attributed to the shifting of groundnut to the soil-rich areas where sugarcane (*Saccharum officinarum*) is grown. Present and future research now include, along with further yield increases, improving quality and reducing costs of production.*

This paper also summarizes the situation of groundnut production in small areas of Bolivia, Paraguay, northeastern Brazil, and Uruguay, and comments upon a recently initiated cooperative South American program to promote groundnut production in these regions.

Résumé

Production et recherche d'arachide en Amérique du Sud: *La superficie totale consacrée à la culture commerciale de l'arachide (*Arachis hypogaea*) en Amérique du Sud est actuellement d'environ 350 000 hectares. Les terrains cultivés les plus importants sont situés en Argentine, dans la province de Cordoba (180 000 hectares) et au Brésil, dans l'état de São Paulo (80 000 hectares).*

*Les zones de production arachidière n'ont pas cessé de baisser entre 1980 et 1990, de même qu'entre 1970 et 1980. La cause principale de cette baisse était la diminution considérable d'extraction de l'huile d'arachide, à mesure que les industries passaient progressivement à d'autres sources d'huile plus rentables, spécialement le soja (*Glycine max*). Toutefois, la baisse de la production totale était moins marquée en conséquence de rendements de récoltes plus élevés. Les rendements moyens au cours des années 1980 étaient de près de 50% supérieurs à ceux des années 1970.*

Les rendements de récoltes les plus élevés obtenus en Argentine et au Brésil sont attribués à l'adoption de technologies disponibles, telles que la rotation des cultures, la lutte chimique contre les mauvaises herbes, les insectes et les maladies et l'amélioration des méthodes de récolte. En Argentine, le remplacement des cultivars valencia et spanish par des cultivars virginia rampants a

1. Groundnut Breeder, Instituto Agronômico, C.P. 28, 13001 – Campinas, São Paulo, Brazil.

2. Groundnut Breeder, Estación Experimental Agropecuaria del INTA, 5988 – Manfredi, Córdoba, Argentina.

Godoy, I.J., and **Giandana, E.H.** 1992. Groundnut production and research in South America. Pages 77–85 *in* Groundnut – a global perspective: proceedings of an international workshop, 25–29 Nov 1991, ICRISAT Center, India (Nigam, S.N., ed.). Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

également joué un rôle important. Au Brésil, les augmentations sont également dues au déplacement de l'arachide vers les zones de sol plus riche, où l'on cultive la canne à sucre (Saccharus officinarum). *Les recherches entreprises et futures comprennent, outre des augmentations de rendement, une amélioration de la qualité et une réduction des coûts de production.*

Cette communication résume aussi la situation de la production arachidière dans de petites zones de la Bolivie, du Paraguay, du nord-est du Brésil et de l'Uruguay et fait des observations sur un programme coopératif récemment entrepris en Amérique du Sud pour promouvoir la production arachidière dans ces régions.

The total commercial groundnut (*Arachis hypogaea*) production area in South America is currently about 350 000 ha. The largest areas cultivated are located in Argentina, in the province of Córdoba (180 000 ha), and Brazil, in the state of São Paulo (80 000 ha). In Brazil an additional 20 000 ha are widely distributed in small areas around the country from latitudes 3°S to 30°S. In Paraguay, 30 000 ha are cultivated. In Bolivia, Chile, Equador, Peru, Uruguay, and Venezuela, the area under groundnut does not exceed 5000 ha.

The areas cultivated continued to decline between 1980 and 1990 as happened between 1970 and 1980. However, the decline in total production was less pronounced because of higher crop yields. Average yields in the 1980s were nearly 50% higher than those of the 1970s.

The greatest reductions in area were in regions where groundnut production was more dependent on the demand for oil extraction, since South American oil industries exported less oil and by-products. These changes caused a gradual shifting of groundnut production towards the marketing of edible groundnuts, either for export or for increased local consumption.

This report emphasizes production in Argentina and Brazil, since these countries contribute more than 80% of the total groundnut production in South America. The major objectives of PROMANI (PRO = program; MANI = groundnut), a South American cooperative groundnut program involving Argentina, Bolivia, Brazil, Paraguay, and Uruguay, are presented.

Groundnut Production in Argentina

Approximately 98% of the groundnut in Argentina is produced in the province of Córdoba. Soils in Córdoba are light-textured, well-drained, sandy loam soils, with approximately 2% organic matter. Soils are well supplied with calcium, magnesium, and potassium, and contain moderate levels of nitrogen and phosphorus. Because of the nutrient status of the soil, fertilization of either the groundnuts or the preceeding crops such as corn (*Zea mays*) or sorghum (*Sorghum bicolor*) is not required.

Córdoba is classified as a semi-arid region, with an annual rainfall of 600 to 800 mm, of which 550–650 mm is received during the October–March growing season. Summer temperatures average 21°C, with maximum daily temperatures of 40°C and minimum temperatures of 12°C. The frost-free period is 235 days.

Changes in area, production and yield over the last 10 years

As shown in Table 1, the groundnut production area of Argentina was reduced by 49% between 1970 and 1980. The reduction occurred because groundnut production was not profitable. Many farmers chose to sow soybeans (*Glycine max*) rather than groundnuts.

Table 1. Average groundnut area, production, and yield in Argentina in the 1970s and 1980s.

Decade	Area ('000 ha)	Shelled production ('000 t)	Seed yield (kg ha^{-1})
1970-79	353	277.4	792
1980-89	180	213.0	1217

Internal prices were influenced by instabilities in international markets that led to an increase in production of less expensive oils from soybean, sunflower (*Helianthus annuus*), and oil palm (*Elaeis* sp).

Although the total cultivated area remained stable at 180 000 ha during the 1980s, production was 23% lower than in the previous decade. Nevertheless, crop yields were over 53% higher, averaging 1217 kg of seed ha^{-1} against 792 kg ha^{-1} during the 1970s.

The increases in yield were attributed to higher yielding cultivars and new crop production technology.

New cultivars played an important role in increased groundnut crop yields. Production during the 1970s was largely (80%) obtained from cultivars of the valencia type (Colorado Irradiado INTA and Blanco Río Segundo). A third cultivar, Blanco Manfredi 68, a cross between virginia and spanish types, was responsible for the other 20%. With the availability of well-adapted virginia runners (Florman INTA and Florunner), growers gradually accepted these new cultivars. By 1989 Florman INTA and Florunner accounted for 80% of the total area and production. The cultivars Colorado Irradiado INTA and Blanco Manfredi 68, on the remaining 20%, have gradually been replaced by the runner types more recently.

The good adaptation of runner cultivars to Córdoba's soil and climate opened possibilities for increasing exports of edible groundnuts, so that Argentina now ranks third after the USA and the People's Republic of China.

Recommended practices and technological progress, 1980–1990

The positive changes that occurred in the last decade were mostly due to improvement in groundnut cropping following locally developed or adapted technologies such as those mentioned below.

Crop rotation. The inclusion of groundnuts into rotation systems with other crops virtually eliminated areas of monocropping. Present recommendations indicate sorghum and corn as the preferred rotation crops in groundnut areas.

New cultivars. As mentioned earlier, the introduction of Florunner and the locally selected Florman INTA helped increase yields and facilitated mechanical harvesting. Present recommendations indicate 1–15 November as the best sowing time for these cultivars. Sowing should be at a rate of 8–10 seeds m^{-1} in rows spaced 70 cm apart.

Weed control. Weed control has been improved by the use of herbicides. Preemergence application of trifluralin is usually recommended.

Disease control. Cercospora and *Phaeoisariopsis* leaf spots, the major groundnut diseases in Argentina, have been better controlled, following local recommendations on the use of fungicides. Two or three fungicide applications are now recommended.

Harvesting. Although some losses up to 25% occur, present harvesting equipment (digger-inverter and combine) has been improved and adapted for harvesting runner types. It is recommended that digging time should be identified when 60–70% of the pods are mature. Combining should be made after 6-10 days of windrowing when seed moisture is at 12-14%. Harvested pods should be stocked in silos or bags.

Groundnut utilization and marketing diversification

Significant changes in groundnut utilization were noticed during the last decade, as shown by the volume of exports of groundnut products (Table 2).

Table 2. Annual exports of groundnut products in Argentina in the 1970s and 1980s.

Decade	Edible nuts (t)	Oil (t)	By-products (t)
1970-79	19 443	78 182	79 441
1980-89	87 737	45 152	43 603

During the 1970s, nearly all of the crop was utilized as oil and groundnut cake. Export of edible groundnut was initiated during the period 1975–79 and registered an average export of 19 443 t per year. This increased to a annual 83 737 t in the 1980s, which represents about 40% of the total annual groundnut production. Internal consumption of edible nuts is estimated at 15 000 t annually.

Oil production decreased by 42% from 1970 to 1980. Only 5% of the present oil production is consumed internally and 95% is exported. Exports of groundnut cake amount to 65% of total production and the remainder is absorbed by the internal market.

Present and future research

Groundnut research in Argentina includes long-term well-documented work on the taxonomy of *Arachis*.

A classification study on groundnut accessions collected in Bolivia, Peru, Ecuador, and other regions of South America is in progress.

Research on groundnut has become intensified since 1984, and it is conducted or coordinated mostly by the Estación Experimental del INTA-Manfredi. Present research involves breeding, crop management, weed and disease control, harvesting, and postharvesting technology.

Research priorities over the next 10 years are:

1. Development of new cultivars, with the following characteristics:
   - Medium cycle of 125-130 days;
   - Tolerance to drought stress at the various physiological stages;
   - Tolerance or resistance to *Cercospora* and *Phaeoisariopsis* leaf spots, with the objective of reducing or eliminating the use of chemicals in disease control;
   - Resistance to *Aspergillus* infection;
   - High oleic/linoleic acid ratio;
   - Low iodine value;
   - Improved content and quality of seed proteins; and
   - Improved groundnut flavor and aroma.
2. Integrated weed management, to reduce the use of herbicides.
3. Improvement of harvesting equipment which involves testing and distribution of new digger-inverters and combines to reduce field losses.
4. Improvement of postharvesting technology to ensure good crop quality.

Future of groundnuts as a crop in Argentina

Future trends in production and marketing of the crop in Argentina depend on the status of the international market, and its effect on processing for oil and cake or for edible groundnut exports. Changes in internal consumption may also affect trends in production.

Further increases in yield and production at the grower level are expected, once improved cultivars and harvesting equipment are available.

ICRISAT's contribution to groundnut improvement

Segregant lines from ICRISAT were sent to Argentina in 1982. Local selections of original ICGSs 1, 4, 5, 11, 12, 19, 21, 26, 31, 32, 34, 36, and 43 are presently included in field trials. One selection, derived from ICGS 5, has been used as a parent in various crosses because of its early maturation and high yield.

Groundnut Production in Brazil

The estimated area of groundnut cultivation in Brazil was 99 916 ha in 1988. Unshelled production was 166 994 t with average yields of 1671 kg ha^{-1}.

Since 1988 the area for production in São Paulo has been around 80 000 ha. Yields of the rainy season crop, which comprises over 80% of the annual cultivated area have ranged from 2000–2100 kg ha^{-1}. Dry season yields average 1500 kg ha^{-1}. Since nearly 90% of total production in Brazil originates from São Paulo, this report is based mainly on information from this region.

Major changes over the last 10 years

The area and production in Brazil has decreased significantly since 1970. Cultivated area declined from 759 000 ha in 1972 to 100 000 ha in 1988 and production of unshelled groundnuts simultaneously fell from 956 000 to 167 000 t over the same period.

The establishment of soybeans as an important cash crop in the country was mainly responsible for this decrease. Groundnut oil has gradually been replaced by soybean oil for the domestic and export markets.

At the farmer's level, groundnut production is regarded as risky in Brazil. The cost of production has been relatively high when compared to other crops and little effort has been made to provide price support for groundnut production, as happens with other agricultural activities.

Significant changes having important socioeconomic implications occurred between the agricultural regions of the state of São Paulo from 1970 to 1990 (Table 3).

Table 3. Regional distribution of groundnut growing areas in the state of São Paulo between 1970 and 1991.

	Regional contribution (%)		
Region	1970-72	1987-89	1990-91
Ribeirão Preto	9.0	31.1	58.0
Bauru	2.5	3.9	2.5
Marilia	23.4	33.0	18.8
Río Preto	6.3	7.4	6.6
Araçatuba	7.6	9.0	6.1
Prudente	50.9	14.9	7.8

In the early 1970s, regions of Marilia and Prudente, located in western São Paulo, accounted for about 70% of the total groundnut area and production. Groundnut was the main agricultural crop and it was cultivated on sandy soils of low to medium fertility, by small farmers with low technological inputs. Most of the 500 000 t produced annually were sold to regional oil factories for exporting and internal consumption.

With the decrease in total production and oil exports, groundnut cultivation gradually shifted to other areas, especially to the region of Ribeirão Preto where as a result of improved technology, higher yield and quality can be attained. The Ribeirão Preto region now accounts for 58% of the area under groundnut production in the state. Groundnuts are mostly grown in rotation with sugarcane. Large areas, averaging over 100 ha, are rented to groundnut farmers by the sugarcane factories for one growing season. Land preparation is also provided, thus reducing the cost of production to the farmer.

Considering both rainy and dry seasons, average yields in São Paulo increased from 1300 to 1500 kg ha^{-1} in the 1970s, and to 1800 kg ha^{-1} in the 1980s. In the Ribeirão Preto region, yields of unshelled groundnuts average 2500 kg ha^{-1}. Yields of up to 4000 kg ha^{-1} can be obtained with the red valencia cultivar Tatu, which is currently grown.

Recommended practices and technological progress, 1980–1990

Growers have been able to adopt recommended improved local practices or introduced foreign technology to help boost production.

Liming and fertilizing. Liming is recommended to increase base saturation to 60% and provide calcium to the podding zone. Fertilizing, as indicated by soil analysis, generally includes 60 kg ha^{-1} of phosphorus and 10 kg ha^{-1} of potassium. Fertilizers with a low nitrogen content, which help to promote nodulation, are also available.

Weed control. Preplant, preemergence, and postemergence herbicides are available and are recommended for infestations of specific weeds.

Control of insects and diseases. Chemical control of thrips is necessary since it is of frequent occurrence in all groundnut crops. Three insecticide spray applications during the early stages of crop growth are recommended. Fungicidal control of late leaf spot (*Phaeoisariopsis personata*) is more frequent. Four applications of sprays are recommended for control of leaf spots in short-cycle cultivars.

Harvesting. Harvesting is partially mechanized. Available equipment includes tractor-pulled root-cutting blades for detaching the plants from the soil, and tractor-propelled threshers. Since cultivars are of the erect type and have low peg resistance, hand labor is still necessary for proper inverting.

Prevention of aflatoxin. Considerable extension information, based on foreign work but adapted to Brazilian conditions, has been undertaken during the last 10 years. Recommended practices to prevent *Aspergillus* infection and aflatoxin contamination are involved in all phases of production and handling.

Varieties

The cultivar Tatu, an old and widely grown valencia variety, still occupies about 80% of the groundnut growing area in São Paulo. It is also probably known by other names in other regions of the country. It is early maturing (90–110 days cycle), presents 3–4 seeds per pod and has pale red testa.

Tatu Branco, another cultivar, is grown in the western region and occupies about 10% of the crop area. It is morphologically similar to Tatu, except for the pale rose color of the testa. It does not respond to favorable growing conditions as Tatu does, but it shows some undefined tolerance to drought and low fertility.

The cultivars Tupà, Oirà, and Poitara were recently released. These seeds are now being distributed to farmers. All three are selections from valencia × spanish crosses, with a cycle of 110–120 days, two medium-size seeds per pod, and a yield 15–20% higher than the cultivar Tatu.

Groundnut utilization and marketing diversification

Considerable changes have occurred in groundnut marketing in Brazil (Table 4), mostly related to the

Table 4. Use of shelled groundnut in Brazil, 1980-1990.

	Oil extraction		Export		Internal market		Seeds	
Year	(t)	(%)	(t)	(%)	(t)	(%)	(t)	(%)
1980	234 500	74	14 000	4	35 000	11	31 500	10
1990	35 700	30	4 000	3	67 400	57	11 900	10

decrease in the demand for oil, as previously described for Argentina.

In 1990, the internal market for edible groundnuts absorbed over 67 000 t of seed, representing 57% of total production. At the same time there was a large drop in exports, especially in oil.

The higher internal demand for the natural product can be explained not only by population increase, but also by a higher consumption per capita. The requirement by the confectionery industry for better quality is also gaining increasing importance. Increased quality improvement, needed at all levels of groundnut production and marketing, is likely to promote an increase in demand for edible groundnuts in Brazil.

Present research and future needs

Several trips to collect *Arachis* germplasm in Brazil have been coordinated by the Centro Nacional de Recursos Geneticos (CENARGEN) Empresa Brasileira de Pesquisa Agropecuaria (EMBRAPA) since the early 1980s. These accessions have contributed to an increased genetic variability for breeding and for taxonomic studies.

In the state of São Paulo, groundnut research has been recently reorganized, especially in the Instituto Agronômico de Campinas. The main objectives are related to reducing costs to farmers and reducing aflatoxin contamination. The development of higher yielding cultivars could make the groundnut crop economically more competitive, if production costs are kept at their current levels.

To meet these objectives, the following areas of research are under way:

- Germplasm introduction, screening and study of resistance to late leaf spot and other diseases in different *A. hypogaea* subspecies;
- Breeding for resistance to late leaf spot;
- Development of a monitoring method for predicting need of spraying to control late leaf spot in susceptible cultivars;
- Integrated control of late leaf spot through partial resistance and monitored chemical control;
- Development of a monitoring method to schedule applications of insecticidal sprays for thrips control;
- Breeding and selection of early-maturing, red seeded valencia/spanish cultivars with improved yield, pod/seed appearance, and shelling;
- Breeding and selection of high-yielding virginia runner cultivars with partial resistance to late leaf spot and other diseases;
- Observations on the progress of aflatoxin formation in the windrow;
- Development of an economic dryer for groundnut growers; and
- Experiments on nutritional requirements of groundnuts grown under rotation with sugarcane crops.

Future research areas include breeding for resistance to *Aspergillus* infection, resistance to thrips, and improvement of the physicochemical qualities of the seed. A survey of virus incidence is also needed. Research on nutrition should emphasize local groundnut requirements in calcium and some micronutrients such as boron and molybdenum.

The future of groundnut as a crop in Brazil

In the last 2 years, it appears that the area under groundnut cultivation in Brazil has stabilized at about 100 000 ha. The good internal prices obtained by producers in 1991 has helped to increase interest in groundnut cultivation in the 1991/92 growing season. This is an indication that the growing area will be at least maintained at the present level for the next few years.

There are also some indications that higher demands from the Brazilian consumer for edible groundnuts may occur in the future. An increase in demand in either the internal or the international markets would depend on additional quality improvements expected in groundnut production and processing.

ICRISAT's contribution to groundnut improvement

The groundnut collection, located at the Instituto Agronômico de Campinas, São Paulo, received ICRISAT's collaboration in its initial stages of organization and evaluation.

Some accessions have also been obtained from ICRISAT's collection. After preliminary observations, two entries, ICG 2224 and ICG 7633, were selected as potentially good sources of resistance to *Aspergillus* infection. ICG 7886 has also been used in crosses for its confirmed resistance to late leaf spot and rust.

PROMANI – A Cooperative Program

PROMANI is a recently initiated cooperative effort aiming to promote groundnut research and extension among South American growing regions. It is coordinated by PROCISUR (Programa Cooperativo de Investigación Agricola del Cono Sur), a cooperative agricultural program for southern countries of South America, sponsored by BID (Banco Interamericano de Desenvolvimento) and the participant countries, Argentina, Bolivia, Brazil (São Paulo and northeastern Brazil), Paraguay, and Uruguay.

PROMANI started in 1990. Initial steps involved a survey of the groundnut production and technology in each region and a ranking of priorities to be cooperatively undertaken.

A summary of the groundnut production situation in PROMANI regions, apart from that already mentioned for Argentina and Brazil follows.

Bolivia

Groundnuts are socially important in Bolivia since they are used traditionally for local human consumption in various ways. As in other regions, their use as a source of edible oil has diminished considerably.

Groundnuts are cultivated in small areas of 1 to 5 ha, distributed in three regions: Valles Templados (localities of Cochabamba, Santa Crúz, and Chuquisaca), Llanos Orientales (Pando, Beni, and Santa Crúz), and Chaco Boliviano (Tarija). Total groundnut area is estimated at 1800 to 2000 ha, and average yields vary from 750 to 1500 kg ha^{-1}, for a total production of 1750 t of unshelled groundnuts.

Groundnut cultivation is entirely manual. All varieties are local and growers multiply their own seeds. Four main local varieties are reported: Coloradito Palmar – an erect type with a 125-day cycle; Cuero Padilla – a semierect type, 135-day cycle; and Bayo Gigante and Colorado Grande – runner types, 145-day cycle. The runner varieties are considered resistant and the semierect varieties tolerant to late leaf spot. Higher yields are obtained with erect and semierect varieties.

Regional research has concentrated on testing local and introduced varieties for yield and disease resistance and experiments on agronomic practices such as plant density and chemical control of weeds, insects, and diseases.

Northeastern Brazil

Northeastern Brazil has good potential for increasing its groundnut area and production under groundnuts. This region is currently seeking alternatives for crop diversification, especially in areas of cotton production, which now face the problem of boll-weevil infestations.

The region is situated at latitudes 3°S to 15°S. The climate ranges from arid to semi-arid, with average annual rainfall of 500–600 mm and average monthly temperatures of 27°C. There is little variation between months.

The area under cultivation is presently around 7000 ha, and is distributed in four or five states. Groundnuts are cultivated by small growers with low levels of technology and farm holdings ranging from 2 to 20 ha. Growers use their own seeds taking advantage of the existing local variability.

Local research was initiated in 1985. The current research objectives are presently a) evaluation and selection of local and introduced germplasm; b) breeding for disease resistance (with emphasis on late leaf spot), drought tolerance, and yield; c) plant density; d) phosphorus fertilization; and e) weed control.

Paraguay

Paraguayan groundnut production showed little change over the last 8 years. Although the cultivated area decreased by 21% (from 38 000 to 30 000 ha), total production decreased by only 7% (from 41 800 to 39 000 t of seeds) over the same period (1983 to

1990). This was due to yield increases from 1100 to 1300 kg ha^{-1}. Present yields are 50% higher than those observed 20 years ago and this is attributed to the introduction of improved cultivars and technology in some regions of the country.

Groundnuts are grown in three regions, which vary in soil and climatic conditions as well as in the level of technological inputs. In the El Chaco region, crops are totally mechanized and concentrated on spanish varieties. At the central region, valencia and spanish type groundnuts are cultivated by small farmers, with low levels of technology and on less fertile soils. Long-cycle, virginia-type groundnuts are cultivated in the fertile soils of the southern region.

Production is commercialized towards the internal market for edible purposes and for oil extraction. Some 5000 t of spanish and virginia groundnuts are exported to Japan and some European countries. Demand by the groundnut oil industry has decreased considerably with simultaneous increases in soybean and cotton production.

Local research deals with comparative trials of local and introduced varieties.

Uruguay

The total area cultivated was 1500 ha in 1990, but this is only one-sixth of the area sown in 1962/63. Present yields range from 700 to 1800 kg ha^{-1} of unshelled groundnuts.

Uruguayan production is concentrated in the northeastern region of the country, and groundnut is traditionally cultivated by small farmers in crop areas of 2–3 ha mostly on acidic, sandy soils with low calcium content. Groundnuts are generally cultivated with family labor and little technology. Seed are sold for edible purposes, to meet local demand. The vegetative parts of the plants are also saved and used as hay for animal feed during the winter.

Growers use their own seeds for sowing. Valencia type varieties predominate. Spanish and virginia types are also grown to a lesser extent, and mixtures of the three types are commonly observed.

Local research has been intensified since 1984 and involves germplasm collection and evaluation, experiments on seed quality, fertilization and chemical control of weeds, insects, and diseases.

Technology Needs and Cooperative Action

In order to develop a program for cooperative action that can be executed by the participant countries, a ranking of common priorities was established by averaging individual ratings on the constraints and/or technology needs as evaluated in each groundnut region. Priorities with average ratings ≥ 6.0 were considered (Table 5).

Table 5. Individual ratings[1] and ranking of priorities based on constraints and/or technology needs for groundnut production in PROMANI regions, 1991.

	Country[2]						
Constraint	Arg	Bol	Bra-SP	Bra-NE	Par	Uru	Average
Postharvest technology	6	9	9	3	9	6	7.0
Harvesting	6	9	6	9	9	2	6.8
Germplasm and varieties	6	9	6	6	9	4	6.6
Late leaf spot	4	9	6	6	9	4	6.3
Calcium	1	4	9	9	9	6	6.3
Drought	9	9	2	6	4	6	6.0
Thrips	1	9	6	1	9	2	4.5
NPK-fertilizer	1	1	4	6	9	4	4.1
Scab	1	6	4	2	9	1	3.8
Sclerotium	2	6	2	2	4	4	3.3
Mites	1	6	1	1	9	1	3.1
Rust	1	6	4	2	2	1	2.6

1. Ratings of priority: 1 = low; 9 = high.
2. Arg = Argentina; Bol = Bolivia; Bra-SP = Brazil (São Paulo); Bra-NE = Brazil (Northeast); Par = Paraguay; Uru = Uruguay.

The highest priorities in the South American groundnut regions lie in the improvement of quality. Harvesting and postharvest technology that are accessible to the various levels of groundnut producers are needed to prevent aflatoxin contamination and ensure good quality especially of edible groundnuts. Calcium supply, also related to quality, is another limiting factor in some acidic, low-calcium soils such as those found in Brazil, Paraguay, and Uruguay.

Varietal improvement is a common objective in all regions, but at different levels. Bolivia, northeastern Brazil, Paraguay, and Uruguay may achieve progress by selecting out local variability or introducing varieties from other regions.

Breeding programs under way in Argentina and Brazil can also provide advanced lines as well as segregating populations to other PROMANI regions to allow local selection.

PROMANI is also proposing the formation of regional germplasm collections of both native and introduced varieties as a means of increasing and maintaining local variability. Argentina and Brazil (São Paulo) will be preparing and distributing a list of their *A. hypogaea* collections.

Except for some native varieties cultivated in Bolivia and Paraguay, other South American cultivars are susceptible to late leaf spots. Commercial groundnut production is dependent on disease control in Bolivia, southern Brazil, and Paraguay, and to a lesser extent in Argentina, northeastern Brazil, and Uruguay.

Information about fungicides, dosage, and efficiency of chemical control are readily available in the major growing areas of Argentina and Brazil. Other regions can adapt this information to their needs. Environmental and economic implications must be considered, especially in areas containing small growers. Reliable methods of monitoring chemical control of either insects or diseases, once available, would help to minimize the use of chemicals.

Development of agronomically acceptable late leaf spot-resistant cultivars would benefit most groundnut growing areas of South America by reducing costs and contributing to quality of production.

Although late leaf spot is the most frequent disease in groundnut fields, others such as rust, scab, and *Sclerotium* can be potentially important. Their frequency of appearance and intensity of damage vary among regions, as shown by the ratings in Table 5. For some regions, a better knowledge of the potential of these diseases is necessary. The use of cultivars with multiple resistance or the maintenance of local variability among cultivars is advisable.

Except for some areas in Argentina, groundnuts are generally grown under rainfed conditions in all regions. Short rainy seasons or long periods of water deficits are yield-limiting in Argentina, Bolivia, northeastern Brazil, and Uruguay. Groundnut cultivation in Argentina and northeastern Brazil is located on semi-arid regions. In most areas, irrigation is not economical unless market prices justify its use.

Breeding for drought tolerance is an important objective, especially for the semi-arid areas of Argentina and northeastern Brazil. The use of early maturing cultivars is preferable in short rainy seasons. Argentina and Brazil have found variability for yield and other characteristics among local and introduced varieties grown under low-rainfall conditions. However, an understanding of drought tolerance mechanisms is necessary to provide information for breeding activities.

ICRISAT's contribution to research and technology in South America at its various levels of groundnut production as discussed above could be very beneficial. Along with the interactions with ongoing research in the major groundnut growing areas, any support to local improvement of production in small-farming regions is of socioeconomic significance.

Discussion

N.R. Bhagat: What is the extent of pod loss in soil during harvest by mechanical harvesters? Could you tell us more about groundnut harvesters in the USA?
T.G. Isleib: Harvest losses are influenced by several factors – soil condition at digging, adjustment of digger blade and angle, ground speed of the digger, variety, combine ground speed, etc. The losses probably range between 5 and 10%. Multi-row harvesters are now available in the USA. They could effectively combine four to six rows of groundnut. Although they are commercially available, it is very expensive to buy them.

Naazar Ali: Seed rate of 100 kg ha^{-1} used at 90 × 10 cm spacing is very high. In Pakistan also, the recommended seed rate is 100 kg ha^{-1} but at 45 × 10 cm spacing. Is there any specific reason for high seed rate in your region for a wide interrow spacing of 90 cm?
T.G. Isleib: Seed rate mainly depends on seed mass and growth habit of the variety. A higher seed rate is used to compensate for seed mortality/damage. The new airtight planters that convey the seed with great precision especially for maintaining intrarow spacing, can substantially reduce seed requirement.

A. Bhandopadyaya: What factors determine the choice of growing different types in the three major groundnut-growing regions in the USA? What proportion of farmers use their own seed for growing their crop?
T.G. Isleib: Three types of groundnut are grown in different regions of the USA based on traditions. However, in the recent past, farmers have shown some interest in types other than those grown traditionally in their region. Very few farmers use their own seed. Most farmers do not have access to the shelling equipment and they necessarily depend on commercial seed.

M.J. Freire: Mechanization and other inputs are high for groundnut production in the USA. What would be the break-even yield and the minimum economic farm size?
T.G. Isleib: The break-even yield should be around 1700 kg ha^{-1} of quota groundnut. Farm size varies from region to region. Most farmers maintain farms of over 450 ha. Farm size tends to be smaller in the Southeast and Virginia-Carolina regions, but there is a trend towards having larger farms by some progressive farmers.

S.M. Fletcher: Is there any further scope for increasing groundnut production in the countries of South and Central America?
I.J. Godoy: For instance, Paraguay and Bolivia have very good conditions for groundnut production. There are good soils and improved varieties of groundnut are available in these countries. But the crop is grown only on about 30 000 ha. There is perhaps good scope for increasing production in these countries.

M.B. Syamasonta: Calcium deficiency is a big problem in the South American region, particularly in Brazil. Do you have any breeding program for acid tolerance?
I.J. Godoy: At present we do not have much research emphasis on breeding for acid tolerance, but there is a possibility of concentrating on this aspect in the near future.

Groundnut in Eastern Africa, 1981–1990

M.A. Mahmoud[1], A.K. Osman[2], P.W. Nalyongo[3], A. Wakjira[4], and C. David[5]

Abstract

*Groundnut (*Arachis hypogaea*) is one of the important legume crops of eastern Africa. The agroclimatic environment of the region is very diverse and the constraints that limit groundnut production are many. The region's groundnut production in 1990 was highest in Sudan with 400 000 t from 600 000 ha, and lowest in Somalia with 2000 t from 3000 ha. Sudan, the principal producer of groundnut in the region, had a decline in production in 1990 compared to the previous year. Egypt had yield levels of 2167 kg ha^{-1} in 1990 as against a world average of 1157 kg ha^{-1} and an African average of 811 kg ha^{-1}. In the last 10 years, the area, production, and productivity of groundnut in the region indicated a considerable fluctuation, and the trent was clearer for Sudan mainly because of frequent droughts in the western part of the country. There was little progress in groundnut improvement in the region, and the low yields are mainly attributed to unreliable rainfall patterns with frequent droughts, lack of high-yielding adapted cultivars, damage by diseases and pests, poor agronomic practices, and limited use of inputs. Scientists of the national programs, in collaboration with regional and international organizations, are making concerted efforts to overcome these constraints and improve groundnut production in the region.*

Résumé

L'arachide en Afrique orientale, 1981–1990: *L'arachide (*Arachis hypogaea*) est l'une des légumineuses les plus importantes que l'on cultive en Afrique orientale. L'environnement agroclimatique de la région est très varié et les contraintes qui limitent la production arachidière sont nombreuses. Le pays qui produisait le plus d'arachide dans cette région en 1990 était le Soudan, avec 400 000 t à partir de 600 000 ha. La production arachidière est la plus faible en Somalie avec 2000 t, à partir de 3000 ha. Le Soudan, principal producteur d'arachide de cette région, a connu une baisse de production en 1990 par rapport à l'année précédente. L'Egypte avait un rendement de 2167 kg ha^{-1} en 1990, contre une moyenne mondiale de 1157 kg et une moyenne africaine de 811 kg ha^{-1}. Depuis 10 ans, la superficie, la production et la productivité d'arachide dans cette région ont indiqué une fluctuation considérable et cette tendance se manifestait surtout au Soudan, principalement à cause des sécheresses qui affectaient fréquemment la partie ouest du pays. L'amélioration de l'arachide dans cette région n'était pas très marquée et la faiblesse des rendements était surtout due à la pluviométrie aléatoire avec fréquemment des sécheresses, à l'absence de cultivars adaptés et à haut rendement, aux dégâts par des maladies et des insectes ravageurs, aux mauvaises pratiques culturales et à un usage restreint des intrants. Les scientifiques des programmes nationaux, en collaboration avec des organisations régionales et internationales font des efforts de concert pour surmonter ces contraintes et améliorer la production arachidière de la région.*

1. Professor, Oilseed Crops Development Project, Arab Organization for Agricultural Development (AOAD), United Nations Development Programme (UNDP), P.O. Box 474, Khartoum, Sudan.
2. Associate Professor of Agronomy, El Obied Agricultural Research Station, P.O. Box 429, El Obied, Sudan.
3. Groundnut Breeder, Serere Research Station, P.O. Box 90, Tororo, Uganda.
4. Center Manager/Lowland Oilseeds Breeder, Institute of Agricultural Research, Melkaweror Research Center, Box 2003, Addis Ababa, Ethiopia.
5. Groundnut Breeder, Institut des sciences agronomique du Rwanda, Karama, B.P. 121, Kigali, Rwanda.

Mahmoud, M.A., Osman, A.K., Nalyango, P.W., Wakjira, A., and **David C.** 1992. Groundnut in eastern Africa, 1981–1990. Pages 89–95 *in* Groundnut – a global perspective: proceedings of an international workshop, 25–29 Nov 1991, ICRISAT Center, India (Nigam, S.N., ed.). Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Eastern Africa, which comprises Burundi, Djibouti, Egypt, Ethiopia, Rwanda, Somalia, Sudan, and Kenya, has a wide range of climates, soils, and crop requirements. About 22% of the total geographical area of the semi-arid tropics lies in this region. Well over 75% of the region has an average annual rainfall between 400 mm and 1000 mm. Average annual temperatures in different ecological zones of the region range from 6°C in the highlands to 45°C in the lowlands.

Agriculture is one of the primary occupations of the people, and attainment of self-sufficiency in food is a paramount objective. Maize (*Zea mays*) and sorghum (*Sorghum bicolor*) are the major staple food crops of the region, and common bean (*Phaseolus vulgaris*), cowpea (*Vigna unguiculata*), groundnut (*Arachis hypogaea*), green gram (*Vigna radiata*), and pigeonpea (*Cajanus cajan*) are the major grain legume crops.

Groundnut Production

Over the period 1981–1990, Africa accounted for 30% of the world's average groundnut acreage, 21% of total production, and 70% of the yield per unit area. Eastern Africa accounted for 16% of the continent's average of groundnut area for the last decade, 17% of production, and 109% of yield.

Groundnut production in eastern Africa is dominated by Sudan, which accounted for 71% of the region's groundnut area and 66% of its production, but only 92% of its yield per hectare (Table 1). Djibouti did not produce any groundnut during the 1980s.

Egypt is notable for its high yield per hectare, which was 260% of East Africa's average and 197% of the world's average (Table 1). This superiority is mainly due to the fact that all Egyptian groundnuts are irrigated, while production in other countries of the region is predominantly rainfed. The scarcity and very high value of farmland in Egypt is another reason for this intensive cultivation. In addition to Egypt, only Burundi and Ethiopia recorded yields higher than the world average.

The area cultivated and production for the region showed great fluctuations during the decade. This was mainly a reflection of fluctuations in Sudan's area and production which, in turn, was a reflection of rainfall and prices. Sudan, and the entire region, never regained the area, production, and yield levels of 1981. Yield for that year was higher than the corresponding world average.

Trade

During 1981–1990, eastern Africa was a net exporter of groundnut and its products, oil and cake. For the 9 years starting in 1981, the region exported a total of 380 285 t of shelled groundnut, 116 625 t of oil, and 592 361 t of cake (FAO 1990, pp. 220, 245-246, 280-281). Total imports of these products for the 9 years were only 82 t of shelled groundnut, 953 t of oil, and 171 t of cake.

Sudan dominated the trade of the region in groundnut and groundnut products. It accounted for 92% of shelled groundnut, 100% of oil, and 98% of cake exported by the region. It had no imports of groundnut or its products. Egypt was second in importance as an exporter of only shelled groundnut (7.7% of the regional total). It took no part in cake trade and was an importer of oil (343 t) in 2 of the 9 years.

Djibouti was the largest groundnut importer in the region, but its imports were confined to oil. Uganda and Burundi had no trade at all in groundnuts and its products. Trade in the remaining countries was negligible, since Ethiopia's exports of groundnut ceased in the mid-1980s.

Advances and Constraints

For progress in research and activities relating to groundnut production and extension during the decade 1981–1990, information was requested from scientists of national agricultural research systems of all the countries in the region, but reports were received only from Sudan, Uganda, Rwanda, and Ethiopia. However, the situation of groundnut for the other countries in the region is also reviewed based on published information (IDRC 1984; ICRISAT 1987; FAO 1990, FAO 1991, pp. 109-110).

Eastern Africa has a vast potential for agricultural production of various cereal and legume crops, but the statistics for the last decade do not really reflect its growth in the production of oilseed crops, especially groundnut. The reasons that limit area, production, and yield of groundnut in many countries of the region are many. However, this situation can be changed through the cooperative efforts of national, regional, and international organizations. ICRISAT and the Centro Internacional de Agricultura Tropical (CIAT) have taken a lead role in exchanging technology and information to promote production of agricultural crops, especially grain legumes, by establishing regional networks in the region.

Table 1. Area, production, and yield of in-shell groundnuts for eastern African countries, 1981-1990.

		1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	Average	Average (%)
Sudan	A[1]	998	950	770	738	399	541	567	580	544	600	669	71
	P	1110	800	413	386	274	379	422	527	449	400	516	66
	Y	1112	842	536	523	686	700	732	909	587	667	771	92
Egypt	A	12	12	11	12	12	14	11	10	12	12	12	1.3
	P	26	24	20	23	23	37	26	29	25	26	26	3.3
	Y	2141	1951	1770	1917	1956	2643	2476	2900	2174	2167	2167	260
Ethiopia	A	35	34	32	32	45	46	40	40	42	43	39	4.1
	P	36	33	31	28	52	53	50	50	53	54	44	5.6
	Y	1037	971	969	875	1156	1152	1250	1250	1262	1256	1128	135
Somalia	A	1	4	4	4	6	6	4	3	5	NA[2]	4	0.4
	P	1	3	3	4	5	5	3	3	3	NA	3.3	0.4
	Y	800	865	650	875	833	833	738	853	681	NA	833	100
Uganda	A	110	120	120	120	120	130	115	142	145	145	127	13.5
	P	80	90	100	100	100	115	118	99	110	120	103	13.1
	Y	727	750	833	833	833	885	1026	697	759	828	813	97
Kenya	A	14	15	5	10	12	12	13	14	14	NA	12	1.3
	P	8	8	3	7	9	9	9	9	9	NA	7.9	1.0
	Y	571	566	600	700	708	708	654	637	644	NA	652	78
Burundi	A	18	13	65	65	65	65	65	70	72	73	57	6.1
	P	15	11	80	80	80	80	80	85	86	87	68	8.7
	Y	833	846	1231	1231	1231	1231	1231	1214	1194	1192	1193	143
Rwanda	A	18	18	19	16	23	23	24	24	25	NA	21	2.2
	P	16	17	20	15	17	18	17	17	18	NA	17	2.2
	Y	914	960	1067	920	768	761	689	705	705	NA	820	98
Total	A	1206	1166	1026	997	682	837	839	883	859	873	941	100
	P	1292	986	670	643	560	696	725	819	753	687	785	100
	Y	1071	846	653	645	821	831	864	928	877	787	834	100

1. A = Area ('000 ha); P = Production ('000 t); Y = Yield (kg ha^{-1}).
2. NA = Information not available.

Source: FAO Production Yearbook, Vols. 37, 39, 41, 43; FAO Quarterly Bulletin of Statistics Vol. 4:1, 1991.

Sudan

In Sudan, groundnuts are produced under two environments.

- Rainfed production accounts for 84% of the country's total crop area, but only 62% of its total production. The crop is grown on sandy soils of low fertility, mostly under low and erratic rainfall with frequent droughts. All the production is by traditional farming on small holdings. Production is virtually confined to the early-maturing spanish types dominated by the variety Barberton (subsp *fastigata* var *vulgaris*). Very few farmers still grow late-maturing traditional runner types.
- Irrigated groundnuts are produced on heavy black cracking clays (Vertisols), by tenants in big parastatal schemes. In this situation, only late-maturing spreading (virginia) types are grown. The variety Ashford dominates in the area, with a minor area growing the variety MH 383.

Research on irrigated groundnuts has been conducted for more than 30 years, during which period all production and protection requirements were investigated. All recommendations for improved practices were made before 1980. The only improvement still vigorously sought is an improved variety or varieties to replace Ashford. None of the over 400 varieties and lines introduced from ICRISAT and the USA since 1978 could outyield the variety Ashford. Between 1979 and 1989, more than 240 varietal crosses were made locally. A line from the cross MH 383 × Florunner was found superior to Ashford in multiseason and multilocational tests and is expected to be released soon.

Kiriz, a large-seeded variety, was released in 1986 for production in the irrigated central region. It was released to meet the special demand for confectionery types, and production was virtually confined to sandy soils in the irrigated areas of the northern region.

Lack of research stations in western Sudan, where most of the crop is grown, precluded in-depth research on rainfed groundnuts on sandy soil. However, with the opening of the El Obied Agricultural Research Station in 1983, such research could be undertaken. In spite of frequent drought years, recommendations on spacing, sowing date and depth, intercropping, digging time, and drying method and period are now ready for on-farm implementation.

However, the most important advance in rainfed groundnut research was the release of the U.S. line EM 9 in 1987 as the new variety Sodiri to replace Barberton. In 12 trials over three seasons and four rainfed locations, the new variety outyielded Barberton by an average of 20.5%, while retaining the well-established market-characteristics plant type of Barberton. Active seed multiplication and extension programs to promote Sodiri are underway.

Extension work in groundnut has been greatly expanded with the support of the International Fund for Agricultural Development (IFAD) and the European Economic Community (EEC) projects, and the United Nations Development Programme (UNDP)/Arab Organization for Agricultural Development (AOAD) oilseeds project. The main extension packages cover the new variety Sodiri and intercropping of groundnuts and pearl millet together with optimum spacings and sowing time. Methods of harvesting and drying to minimize aflatoxin incidence is a part of these packages.

The main constraints to more rapid advances are mainly shortages in funding the research programs and depletion of trained manpower. The extension service is not adequately equipped to cope with the needs of the large numbers of small traditional farmers in rainfed areas. Quality seed production is undertaken only by a government organization that could not satisfy the demand. Continuous drought has led to severe shortage of seed for sowing.

Uganda

Groundnut is the second most important legume crop grown in Uganda, after common beans. It is a very popular and useful crop throughout the country, especially in the eastern and northern regions where groundnut has become part of the people's culture. Groundnut has great potential as an export crop for this country although its export stopped way back in the 1970s. During the decade under review, the production trend and yield per unit area showed a marked decline nationally. This decline can be attributed to numerous production constraints of which groundnut rosette virus disease was the most limiting.

Groundnut research in Uganda is poorly organized and funded. During the last decade, the main objectives of the groundnut improvement program at Serere Research Station were:

- To develop resistant cultivars to rosette virus disease;
- To incorporate resistance to foliar fungal diseases (leaf spots) into adapted early-maturing groundnut cultivars;
- To establish a gene bank;
- To maintain and evaluate cultivars for stability;
- To screen germplasm for resistance to bacterial wilt;
- To utilize induced mutations as a breeding method; and
- To test advanced breeding lines and selections for adaptability under the various ecological zones of Uganda.

During the last decade, only one groundnut variety, Red Beauty, a red valencia type was produced and marketed by the Uganda Seeds Project. Research could neither provide new varieties nor resupply the seeds for varieties that are on the national variety list, mainly for those lost from the Uganda Seeds Project. These varieties include Mani Pintar, Makulu Red, Bukene, and Roxo. The failure to have all the above varieties in production is partly attributed to Uganda Seeds Projects, which lacked the capacity to handle them, and partly due to inefficient research management.

Adoption of research recommendations by farmers was weak or absent due to poor linkages between farmers and researchers. However, in 1986 IFAD and the World Bank initiated the Agricultural Development Project to boost food production in eastern and northern Uganda, the heartland of groundnut production. Its adaptive research, on-farm trials, and Training and Visit extension approaches succeeded in convincing farmers to adopt some research recommendations. These included plant spacing and time of sowing, site selection, and spraying with insecticides to control the rosette-causing vector.

Severe shortage of funds for groundnut research, poorly organized research structure, shortage of trained personnel and facilities, and a weak government commitment to research in this crop represent the main constraints on research.

Ethiopia

Although groundnut research in Ethiopia was initiated in the 1960s, systematic work was begun only a decade ago when adequate funds and human resources were provided. The overall aim of this program is to increase the productivity of groundnut with the use of improved production practices.

Both the past and present research activities on groundnut in Ethiopia, particularly at Melka Werer Research Center, are geared towards searching for high-yielding varieties together with suitable agronomic practices. As a result, during the last decade three varieties, NC 4X, NC 343, and ICG 94, were released and the salient features of these varieties are shown in Table 2.

The data in Table 2 are the means of 3 years in eastern and western parts of Ethiopia. They are all large-seeded and late-maturing virginia types introduced from the USA and ICRISAT.

In the 1988–1990 trials, the three ICRISAT varieties ICG 273, ICGS 69, and ICGS 77 performed very well and are expected to be released in the near future. ICG 273 is an early-maturing valencia type with good seed and pod qualities, despite its low yield potential. The other two are virginia types adapted to specific sites within the country.

Table 2. Three groundnut varieties released in Ethiopia and their characteristics.

Variety	Year of release	Pod yield ($t\ ha^{-1}$) Irrigated	Pod yield ($t\ ha^{-1}$) Rainfed	Oil content (%)	Days to maturity
NC 4X	1986	5.0-7.0	2.0-4.0	42-49	130-160
NC 343	1986	4.0-6.0	2.5-3.0	45-50	140-160
ICG 94	1988	5.0-7.0	3.0-5.0	44-50	130-160

Optimum sowing dates, spacing, irrigation, and weeding practices have been established by research. No significant yield response resulted from use of fertilizers or sowing methods. The major insect pests and diseases were identified and recommendations on control were given.

Seed production is done by the research center and the farmers themselves. Extension services are lacking and this is one of the major factors limiting groundnut production. The other problems are drought, pests, poor incentives (low prices), shortage of oxen for small farms and machinery for large farms, and allocation of marginal soils for the crop's production.

Research constraints include lack of high caliber research staff, laboratory facilities and equipment, and poor extension linkages between research stations and producers.

Rwanda

Groundnut is the third most important grain legume crop in Rwanda, after beans and peas. It is grown mainly in the low and middle altitudes where mean temperatures exceed 19°C. Generally, the confectionery types are grown and consumed throughout the country.

Groundnut area has increased by 25% since 1979. However, total production remained virtually stable due to a progressive decline in yield per unit area.

The three varieties already released, HN-G18, HN-G17, and HA-D30, have a mean pod yield of 1721 kg ha^{-1}. Preliminary trials conducted between 1980 and 1990 have revealed 11 high-yielding varieties: 7 from ICRISAT and 4 from Cameroon. Their pod yields ranged between 2708 and 5651 kg ha^{-1}, with an average of 3710 kg ha^{-1}. Most of them were tested only once but the variety ICGS 27 averaged 2742 kg ha^{-1} in five tests in 1986-87. Evaluation of these varieties for yield and response to early leaf spot (*Cercospora arachidicola*), late leaf spot (*Phaeoisariopsis personata*), rosette, and thrips is continuing.

In other trials, varieties were evaluated for resistance to leaf spots and thrips. Preliminary results indicated that these varieties possessed tolerance to either one of them or both.

Groundnuts are widely grown in intercropping systems. Trials conducted between 1983 and 1988 have shown that intercropping groundnuts with beans gave the best results, followed by dwarf sorghum. Groundnuts with maize gave poor results, although it is the most common association.

Burundi

In Burundi, most land under cultivation is devoted to subsistence crops. Output of cash and food crops has fluctuated, owing to the effects of drought, soil erosion, and price controls. Groundnut is grown at altitudes between 850 m and 1500 m, but the main concentration is in the lower altitudes, especially Imbo (800–1000 m) and Moso (1200–1300 m) regions. It is produced mostly by small farmers of limited means; total production in 1990 was estimated at 87 000 t from 73 000 ha, with an yield average of 1192 kg ha^{-1}.

Groundnut has long been grown in kitchen gardens for its snack and confectionery value. But in recent years, it has been used as a source of edible oil, which will possibly lead to the extension of the area under cultivation.

Groundnut can be grown in either of the two cropping seasons in the country. It is grown more extensively in the second cropping season (February to May), often in pure sands after maize. Early drought can cause serious damage to the crop, resulting in considerable yield losses.

Groundnut production in the country can be considerably increased provided the farmer has varieties that tolerate drought and diseases. Since 1985, research has been in progress to identify varieties resistant to groundnut rosette and drought. Groundnut varieties with higher oil content are also in demand. The use of groundnut for extracting edible oil is a new incentive for farmers to increase production.

Egypt

In Egypt, cultivation is concentrated in the Nile and Delta regions and less than 5% of total land area is cultivated. Production, which is highly labor-intensive, has been disappointing due to price controls, fragmented land tenure, increased soil salinity, and consumer preference for imported food. Current government policy emphasizes increased use of machinery and fertilizers, stabilization of farm prices, and canal drainage.

Groundnut is one of the most important cash crops in the country for farmers and for export. The most important areas of production are the eastern Delta region (Ismailia and Shankia Provinces) and middle Egypt (Giza Province) where about 85% of the total area of the country is cultivated. Groundnut grown in the country is of semi-spreading type and is large podded with two seeds.

Groundnut improvement work is carried out by the Oilcrops Research Section at the Field Crops Research Institute, Agricultural Research Centre, Giza, which has made substantial progress in developing varieties suitable for the country. Although the area under groundnut cultivation has been stable for the last 10 years, there is a significant increase in yield per unit area.

The groundnut improvement program and the extension network are presently engaged in increasing production by introducing the crop to newer areas and sowing with suitable high-yielding varieties. To further boost production in the country, the groundnut improvement program is aimed at 1) evaluation of introduced and local strains for yield and disease resistance; 2) conducting yield trials to identify the most promising lines; and 3) determining the best cultural practices, and establishing demonstration fields with good management practices in collaboration with the extension department.

In recent years, various trials were conducted to determine the effects of rhizobial inoculation, macro and micro elements, gypsum application, and to identify varieties responding to these cultural practices.

Kenya

Groundnut is an important legume crop in Kenya, with a ready market for raw nuts and processed products such as roasted or fried pods and seeds, confectioneries, peanut butter, and edible oil. The dried or fresh haulms and oilcake are important sources of animal feed. In 1990, the production of groundnut was 9000 t from 15 000 ha with a productivity of 621 kg ha^{-1}.

Western and Nyanza Provinces of western Kenya are the major groundnut-producing areas, with scattered pockets of production in the Rift Valley and Eastern Provinces. The main constraint to production is lack of good quality seeds for sowing. Diseases such as groundnut rosette and leaf spots, and insect pests such as leaf miner, jassids, and thrips cause considerable damage, resulting in significant crop losses. Postharvest handling, accompanied by low and fluctuating market prices, also affect production.

Little effort has been directed towards the improvement of groundnut in the country, despite its importance. Eight varieties were evaluated at the Regional Research Station, Kakamega, during 1984–89, and two varieties, Makulu Red and Mani Pintar, gave higher yields than the Red valencia and Homa Bay local varieties. However, no large scale seed production program for these varieties has been initiated.

The Eastern Africa Regional Cereals and Legumes (EARCAL) Program of ICRISAT, based in Kenya, has introduced improved germplasm from the SADCC/ICRISAT Project in Malawi and tested them at Perkerra, Kiboko, and Katumani. Preliminary observations indicate that 11 spanish-type varieties (ICGVs SM 87079, 86066, 87040, 86043, 86054, 85001, 86015, 87009, 86053, 87080, and 85053) and 1 virginia-type variety (ICGV SM 88734) performed very well, and efforts are being made to grow them under multilocational tests to identify varieties adapted to different agroclimatic conditions.

Based on research done in Kenya and elsewhere, the Kenya Agricultural Research Institute is preparing an extension bulletin of packages of improved cultivation practices for the benefit of extension workers and groundnut farmers in the country. Some of the agronomic practices recommended include seedbed preparation, seed treatment and appropriate time of sowing, spacing and seed rate, depth and method of sowing, intercultivation and weed control, time of harvesting, threshing, drying, and proper storage.

Considering the present and future needs, the national program has identified the priorities in close consultation with EARCAL and other support programs. They include 1) periodic surveys for production practices, and biotic and abiotic stresses; 2) varietal adaptation tests in different agroclimatic zones; 3) seed multiplication and production programs; 4) improved farm tools for field operations; 5) marketing, pricing, and agroprocessing research; and 6) crop production and protection research.

Somalia

In Somalia, agriculture is mostly a pastoral form of production and about 70% of the population depends on raising livestock. As a whole, the country presents a harsh environment, a part of it is semi-desert. Only 1% of the land surface is used for agriculture, although 9% is potentially arable. The country's most important agricultural areas lies between the Juba and Shebeli rivers. Subsistence farmers grow maize and sorghum. Wheat (*Triticum aesitivum*), rice (*Oryza sativa*), and vegetable oil are imported. Somalia accounts for only 2000 t of groundnut from 3000 ha with a productivity of 740 kg ha^{-1}.

The dryland farming system is confined to sorghum, maize, groundnut, and cowpea. Research necessary for the improvement of dryland agriculture must be aimed at achieving stable production. There is too little diversity in the cropping options. However, changes in the prices of crops encourage farmers to move into those crops that could provide a cash return. Some yield trials of groundnut were conducted at the Agricultural Research Station, Banka, that identified cultivars suitable to Somalian conditions.

Djibouti

In Djibouti agriculture is an underdeveloped sector due to poor terrain (mostly desert). About 95% of food requirements are imported. Information on crops is very limited.

References

FAO. 1990. 1989 Trade Yearbook, vol. 43. Rome, Italy: FAO.

FAO. 1991. 1990 Production Yearbook, vol. 44. Rome, Italy: FAO.

ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1987. Research on grain legumes in eastern and central Africa: summary proceedings of the Consultative Group Meeting for Eastern and Central African Regional Research on Grain Legumes (Groundnut, Chickpea, and Pigeonpea), 8–10 Dec 1986, Addis Ababa, Ethiopia. Patancheru, A.P. 502 324, India: ICRISAT.

IDRC (International Development Research Centre). 1984. Proceedings of a Workshop on Oil Crops, 3–8 Sep 1983, Cairo, Egypt. Ottawa, Canada: IDRC. 178 pp.

Assessment of Groundnut Research Achievements in the Savannah Regions of West Africa

R. Schilling[1] and S.M. Misari[2]

Abstract

*Groundnut (*Arachis hypogaea*) research in West Africa was initiated in the 1920s and conducted on three major locations: Samaru, Nigeria; Bambey, Senegal; and Niangoloko, Burkina Faso. Breeding led to the selection of a number of productive varieties as regards drought tolerance, disease resistance, earliness, dormancy, and adaptation to the edible market demand. Long-term agronomy trials indicate that applying only mineral fertilizer will not prevent soil acidification by cation reduction, resulting in reduced yields. Maintaining the organic matter content of the soil is essential if the reproducibility of a cropping system based on alternating groundnut and cereals is to be ensured in the Sudan-Sahelian Zone.*

*The phytosanitary problems in West Africa are becoming more acute as crop rotations become shorter and continuous cropping is expanded. Research work is based on five major topics: emergence disease and pest protection – inexpensive and highly effective seed-dressing treatments are applied; leaf disease control – rosette-resistant varieties are available and integrated pest managements of rust (*Puccinia arachidis*) and leaf spot (*Phaeoisariopsis personata*) diseases are being investigated; millipede (class: Diplopoda) control – emergence protection and the use of baits have been developed; aflatoxin control – preventive methods at the field level and corrective control at the industrial level have been developed; and nematode control – a control method was developed and applied full-scale in northern Senegal.*

For postharvest technology, current research is helping to develop processes for more effective improvement of groundnut products. Disinfection of stocks, refrigerated seed storage, and vacuum storage of seed have been developed. Industrial production of ready-to-use seed will be undertaken in the near future in Senegal.

Mixed research and development operations are under way in different fields, notably seed and edible nut production and processing. They enable researchers to follow closely the requirements of the producer and consumer, and ensure the coherence and effectiveness of the program as a whole.

Résumé

Evaluation des résultats de la production arachidière dans les régions de savane d'Afrique occidentale: *La recherche sur l'arachide* (Arachis hypogaea) *a été lancée au cours des années 1920 en Afrique de l'Ouest à trois lieux principaux: Samaru (Nigéria), Bambey (Sénégal) et Niangoloko (Burkina Faso). La sélection génétique a permis la mise au point d'un certain nombre de variétés productives en ce qui concerne la tolérance de la sécheresse, la résistance à la maladie, la précocité, la dormance et l'adaptation au marché des produits comestibles. Les essais agronomiques à long terme indiquent que l'épandage seulement d'un engrais minéral n'empêche pas l'acidification du sol par la réduction de cation, provoquant une réduction des rendements. Il est*

1. Deputy Director, Annual Oilcrops Division, Institut de recherches pour les huiles et oléagineux (IRHO), Centre de coopération internationale en recherche agronomique pour le développement (CIRAD), B.P. 5035, 34032 Montpellier cedex 01, France.

2. Deputy Director (Extension), Institute for Agricultural Research, Ahmadu Bello University, P.M.B. 1044, Samaru, Zaria, Nigeria.

Schilling, R., and **Misari, S.M.** 1992. Assessment of groundnut research achievements in the Savannah regions in West Africa. Pages 97–112 *in* Groundnut – a global perspective: proceedings of an international workshop, 25–29 Nov 1991, ICRISAT Center, India (Nigam, S.N., ed.). Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

essentiel de maintenir la teneur en matière organique du sol afin d'obtenir une production soutenue d'un système de culture basé sur une rotation de l'arachide et des céréales dans la zone soudano-sahélienne.

*Les problèmes phytosanitaires de l'Afrique occidentale deviennent de plus en plus aigus à mesure que les rotations de culture deviennent plus brèves et la culture continue se répand. Les travaux de recherche se basent sur cinq éléments majeurs: la maladie au moment de la levée et la protection contre les insectes ravageurs—des traitements peu coûteux et extrêmement efficaces pour l'enrobage des semences sont appliqués; la lutte contre les maladies foliaires—des variétés résistant à la rosette sont disponibles et les chercheurs travaillent en ce moment sur une lutte intégrée contre la rouille (*Puccinia arachidis*) et la cercosporose (*Phaeoisariopsis personata*); la lutte contre les mille pattes (groupe: Diplopoda)—la protection au moment de la levée et l'usage d'appâts ont également été développés; la lutte contre les l'aflatoxines—des méthodes de prévention au niveau du terrain et la lutte corrective au niveau industriel ont été développées; et la lutte contre les nématodes—une méthode de lutte a été développée et appliquée sur grande échelle dans le nord du Sénégal.*

Pour la technologie post-récolte, les recherches actuelles aident à mettre au point des processus pour améliorer plus efficacement les produits arachidiers. La désinfection des stocks, des stockages réfrigérés des semences et l'emballage sous vide des semences ont été mis au point. La production industrielle de semences prêtes à être utilisées sera entreprise sans tarder au Sénégal.

Des opérations mixtes de recherche et de développement sont déjà entreprises dans différents domaines, notamment pour la production de semences et de graines comestibles et leur traitement. Ceci permet aux chercheurs de suivre de près les demandes des producteurs et des consommateurs et d'assurer la cohésion et l'efficacité du programme dans son ensemble.

Groundnut (*Arachis hypogaea*) research in the West African Savannah regions was initiated as early as the 1920s at the Institute for Agricultural Research, Samaru, in Nigeria and in 1930 at the Bambey Research Station in Senegal. Research on groundnuts became important from 1950 with the establishment of the Institut de recherches pour les huiles et oléagineaux (IRHO) in Senegal and Burkina Faso. Research activities also gained impetus thereafter in other countries, notably Gambia, Ghana, Sierra Leone, and Côte d'Ivoire. With the debut of the United States Agency for International Development (USAID)-Peanut Collaborative Research Support Program (CRSP) in the early 1980s, research on specific but common problem areas in selected countries in the region resulted in an increase in groundnut research. The creation of the Conférence des responsables de recherche agronomique africains (CORAF) Groundnut Network in 1987, which coincided with the inauguration of the ICRISAT Sahelian Center (ISC) at Sadoré, Niger, provided a significant back-up and complementarity, as well as new perspectives on national research efforts on groundnuts in the region.

The need for research cannot be overemphasized in view of the reduced production of groundnuts particularly during the 1978–1989 period in most groundnut-producing West African countries (Table 1). Reduced production was most marked in Niger and Nigeria. Despite declining production, research has contributed substantially to crop intensification. This paper describes major groundnut research achievements in the Savannah regions of West Africa.

Varietal Improvement and Physiology

Fundamental research (on breeding and developing assessment and screening tests) is mostly carried out in Nigeria (Samaru), Senegal (Bambey), and Burkina Faso (Niangoloko). The last two of these stations cover problems in the Sudan-Sahelian Zone (where the major constraint is drought) and the Sudan-Guinean Zone (where the major constraint is disease). Samaru covers both problems. The programs have changed considerably in terms of goals and the methods used to achieve them. These changes were reflected in the complete renewal of the seed on offer to growers in West Africa, shifting from low-yielding local, creeping varieties with small seeds and a 120-day cycle, to a range of high-yielding erect varieties, better adapted to drought, tolerant of certain diseases, or with characteristics making it possible to sell the seeds to more lucrative markets as edible groundnut. Varieties distributed in Senegal vary depending on the evolution of climatic conditions. The effective production and distribution of seeds each year is determined by the results of research and by government policy.

Table 1. Groundnut production (t) in shell for West African countries, 1970-1989.

	1970	1971	1972	1973	1974	1975	1976	1977
	1978	1979	1980	1981	1982	1983	1984	1985
Country	1986	1987	1988	1989				
Benin	47 247	42 237	41 772	60 034	41 680	34 650	61 108	64 246
	63 727	66 102	62 839	51 800	35 438	33 595	57 505	69 176
	60 241	52 756	71 789	70 417				
Gambia	125 000F[1]	136 000F	115 000F	151 500	151 500F	159 500F	148 000F	105 000F
	133 400	67 000	60 200	108 900	151 400	113 800	105 100	75 800
	110 350	119 950	98 360	132 701				
Ghana	101 600	101 600	89 200	127 000	156 000	110 750	113 400	81 000
	83 000	107 000	142 200	125 900	111 100	91 100	167 000	140 000
	190 300	190 700	229 600	200 000				
Guinea	74 900F	75 600F	76 400F	77 207	77 987	78 774	79 950	80 730
	81 537	82 352	83 900	84 100	84 500	76 500	81 600	74 100
	70 000F	60 000F	50 000F	44 751				
Côte d'Ivoire	42 500	40 800	41 000	43 500	46 400	48 800	49 000	48 800
	49 800	51 700	81 000	85 000	90 000	80 000	102 000	108 000
	112 000	116 000	119 000	137 000*[1]				
Liberia	2 000*	2 100F	2 100F	2 200F	2 400F	550F	2 660F	2 700F
	2 750F	2 800F	2 800F	2 800F	2 900F	3 000F	3 000F	3 000F
	3 200F	4 000F	4 000F	4 000F				
Mali	158 000	152 000*	134 600*	130 200*	160 000*	205 000	230 000	238 500
	164 358	145 554	134 549	128 167	94 280	75 000	54 000	85 065
	107 015	100 680	82 500	115 000*				
Mauritania	3 000*	2 000F	1 000F	980*	1 000F	2 000F	3 000F	3 000F
	3 200F	600	700	1 200	1 500	1 700	1 600F	1 600F
	1 800F	1 900F	1 900F	2 000F				
Niger	204 600	256 500	260 200	77 056	129 085	41 760	79 200	82 300
	98 800	88 468	126 100	101 800	87 500	73 700	30 000	54 500
	60 000*	40 530	45 000*	80 000*				
Nigeria	1 581 000	1 386 000	1 350 000	877 000	1 935 000	458 000	460 000	603 000
	701 000	507 000	471 000	419 000	396 000	591 000	546 000	532 000
	696 000	612 000	540 000	700 000F				
Guinea-Bissau	38 000F	28 750F	33 400F	38 000F	34 500F	37 000	45 000	29 500F
	35 000F	35 000F	30 000F	30 000*	30 000*	22 000*	30 000*	27 000
	29 000	30 000*	35 000*	30 000*				
Senegal	589 950	997 120	586 900	692 779	1 008 794	1 444 093	1 231 500	518 956
	1 061 082	676 000	523 003	872 319	1 004 023	511 556	682 416	586 658
	841 052	963 100	722 900	844 225				
Sierra Leone	20 600	15 100	14 100	14 500	15 000	15 000	15 300	15 300
	15 000	15 000	10 000*	10 000*	15 000	13 500	14 000F	15 000F
	18 147	19 000F	19 000F	18 000F				
Togo	22 000	25 000	16 842	17 190	18 545	19 900	16 301	14 456
	17 820	24 122	24 488	27 641	17 611	15 916	23 080	31 486
	34 802	31 654	25 237	27 550				
Burkina Faso	67 702	66 182	60 408	62 865	88 900	87 200	72 686	57 073
	73 858	77 831	53 943	77 667	70 658	82 316	83 000	123 464
	151 850	145 857	160 735	130 549				

1. F = FAO estimates, * = Unofficial figure.

Source: FAO Yearbooks.

Two major subprograms can be distinguished and are discussed below.

Drought tolerance subprogram

The drought tolerance subprogram launched in Senegal now covers central and northern Burkina Faso and involves a wide range of partners in geographical areas affected by drought (e.g., northeastern Brazil, Botswana). After the general drought in the early 1970s, breeding for drought resistance and short maturity cycle have been given research priority in Nigeria, Ghana, Mali, and Niger.

Physiologists and breeders have been working together in these countries for several years, and have identified a few varieties that may be drought tolerant.

Various drought tolerance techniques have been used and a set of tests have been developed. The tests were applied to the collection of groundnut varieties available in Senegal. Varietal trials were carried out in the field under natural or artificial drought conditions, which led to the distribution of variety 55–437, offered for extension in the northern part of the groundnut basin, the most severely drought-affected area (400–650 mm rainfall). This variety, which is currently released for commercial production in Niger and the drier zones of Nigeria, Chad, Gambia, and Cameroon (Table 2), is being used as a parent in the program underway at Samaru, Nigeria, and at the ICRISAT Sahelian Center (ISC), Niamey. The variety SAMNUT-18 (RRB) released in Nigeria has 55-437 as one of the parent sources. The lack of seed dormancy typical of spanish and valencia types means that there is a risk of immediate germination if the soil is still damp at the time of maturity: breeding was therefore geared towards obtaining drought resistant and dormant types destined to minimize this drawback in areas that are subject to late rainfall (600–900 mm). Hence, variety 73-30, with a 95-day cycle, and 73-33, with a 105-day cycle, were obtained from spanish × virginia crosses. This material is unique, and was introduced by ICRISAT into collections and varietal trials in most producer countries in the semi-arid zone. It has been very widely distributed in Senegal and Gambia (Table 2). The varieties are currently under intensive evaluation in Guinea.

Drought in the Sahel and Sudan-Sahelian Zone can take two forms:

- Short rainy season and low rainfall, typical of higher latitude regions; and
- Long rainy season, but often of irregular distribution and often inadequate total rainfall; this occurs frequently in the central and southern zones.

In the northern region, the goal is to develop breeding programs geared primarily towards producing early-maturing varieties, from parents with a 75–90 day cycle. In the central and southern regions, the aim is to develop varieties with physiological characteristics that will enable them to withstand periods of drought without suffering irreversible damage; the late-maturing varieties have a higher production potential and their ability to recover after drought at the start or in the middle of their cycle means that they are often chosen in preference to early varieties. A drought adaptation ideotype was defined, on the basis of three main physiological characters:

- Root growth,
- Protoplasmic resistance, and
- Optimum stomatal transpiration.

For a given type of drought, the results enable a definition of the adaptation characteristics required of the preferred ideotype. Four tests were developed to enable screening of around 800 individuals in each breeding cycle, based on protoplasmic resistance to heat and drying, by measuring electrolyte escape, on water loss regulation measured using detached leaves, and on rooting characteristics, studied in a rhizotron.

Productivity improvement subprogram

The productivity improvement subprogram covers and combines the other topics. It takes into account the main yield components and the quality of the products obtained, depending on local production conditions. The following traits are important to breeders: yield (pods, haulms, emergence, and shelling), ecological adaptation (cycle length, dormancy, drought tolerance, and disease resistance), response to cropping techniques (soil preparation, fertilization, and mechanization), and product quality (oil and amino-acid composition, and commercial and organoleptic characteristics).

Nearly 50 varieties are currently being commercially multiplied in various West African countries (Table 2). Most of them were obtained at the breeding centers at Bambey, Niangoloko, and Samaru, and then very widely distributed throughout the region, in Cameroon, and in zones of southern Africa with a similar climate. They were all chosen because of their

Table 2. Some improved groundnut varieties under commercial production in West African countries.

Variety	Burkina Faso	Benin	Cameroon	Ghana	Gambia	Guinea	Mali	Niger	Nigeria	Chad	Togo	Senegal
47-16								x[1]				
55-437			x		x			x	x	x		x
73-27												x
73-30												x
73-33					x							x
40-16								x				
57-422								x				x
48-115A			x		x							
48-115B									xN[2]			
48-37		x						x				
RRB									xN			
28-204								x				
28-206			x		x		x	x				x
IB 66			x									
57-313												x
47-10							x					
69-101	x	x							x			x
RMP 12	x	x						x	x		x	
RMP 91	x	x	x						x		x	
KH 149A	x							x				
KH 241D	x											
59-426	x											
TE 3	x										x	
TS 32-1	x	x								x		
GH-119-20			x									x
K1332-781			x									
M513-771			x									
90 Saria	x											
CN 14	x											
554.761									x			
Spanish 205									x			
Spanish 207-3				x								
M25.68									x			
MK 146				x								
MK 374									x			
MK 383				x								
Mani Pintar				x								
Florispan Runner				x								
Natal Common				x								
Shitaochi				x								
Tirik				x								
Philippine Red				x								
Kumawa				x								
FMIX				x								
Samaru 38									x			
Samaru 61									x			
Georgia											x	
De'li Rose										x		
756-17						x						
BS-7												
ICGVs 86053, 86551, 86556, and 87119						?[3]						

1. x = Most widely grown varieties.
2. N = Newly released.
3. ? = Promising varieties, grown elsewhere but still under local adaptation trials.

Table 3. Characteristics of the main groundnut varieties distributed in West Africa.

Variety	Early (<100 days)	Dormancy	Drought tole-rance	Rosette resis-tance	Shelling rate >70%	100-seed mass >50 g	Suitable edible/ confec-tionery
55-437	X		X		X		X
73-30		X	X		X		
47-10	X				X		X
Te3	X		X				
Ts32-1	X		X				
KH-149 A	X			X			
KH-241 D	X			X			
55-422		X			X	X	X
73-33		X	X		X	X	
28-206		X			X		
69-101		X		X	X		
57-313		X			X		
RMP 12		X		X	X	X	
GH119-20		X				X	X
756 A		X				X	X
73-27		X			X	X	X
73-28		X			X	X	X

desirable traits (productivity, erect habit, oil content, and simultaneous maturity). Important traits of some of these varieties are given in Table 3.

Agronomy and Cropping Systems

The apparent decline in groundnut production in West Africa has been partly due to nonadoption of improved agronomic practices for obtaining high yields. Unfavorable climatic conditions, characterized by frequent droughts, high temperatures, and a decline in soil productivity following continuous cultivation, are exogenous factors that have resulted in low yields. Results from research institutes in the region have shown, however, that recommended production practices for obtaining high yields include selection of good quality seed for sowing, a weed-free seedbed, timely sowing, maintaining a high plant population, application of fertilizers, weed and disease control, and timely harvesting.

Despite these recommendations, crop husbandry practices for groundnuts in large areas of West Africa have remained unimproved and the crop is still a subsistence crop. Farmers grow the crop with minimum inputs, which normally entails sowing poor-quality seed of traditional varieties as a component of mixed-cropping systems with inadequate weeding and no chemical fertilizers or pest management practices.

Increased groundnut productivity is sought both from improved varieties and by developing cropping systems likely to make the best possible use of the seed, taking account of:

- Environmental factors (the need to maintain and improve soil fertility on a long-term basis), and
- Socioeconomic constraints affecting the rural environment (land availability, equipment and input costs and installation, grant and credit policies, etc.).

Intervention strategy: restrictions on intensification

Groundnut research has included studies of the socioeconomic environment of production, which is a basic constraint on the application of research results. Prices and price fluctuations are a determining factor: purchase price, harvest prices, price paid for inputs, and expected relative income govern the farmer's technical decisions and market opportunities. Groundnut, which is a 'driving' crop in the Sudan-Sahelian Zone, proves the suggestion that pricing policies are not usually in accordance with official declarations of intention and do not make the most of the technical and financial resources that are available for development. There is no other way of explaining the erratic use of fertilizers in West Africa and the dramatic decline in their use over the past decade; the oft-proclaimed intensification policies sometimes saw the denial of credit and a tripling of fertilizer prices, which resulted in the almost total removal of fertilizers from groundnut and other rotation crops.

This situation makes it logical to recommend the methodical and widespread use of so-called light techniques in the small-holder environment, in preference to inevitably sporadic and expensive heavy practices, limited to a few farmers who can afford them, e.g., the ploughing/deep phosphate applications/high annual fertilizer rate combination, which is no longer being applied in Senegal. This realistic move should be continued.

Farming systems

Groundnut intercropping. Groundnuts play a significant role in the farming systems of West Africa. Although it is grown as a sole crop to a certain extent, the widespread traditional practice throughout the region involves intercropping with cereal crops, particularly sorghum (*Sorghum bicolor*) and millet (*Pennisetum glaucum*). The production of groundnut as a sole crop was first dictated by the colonial emphasis on groundnut as a cash crop. Therefore, sole cropping research results were not applicable, and therefore not adopted by farmers for the traditional mixed cropping systems. It is only relatively recently that research on mixed/intercropping systems has been initiated.

Several advantages of intercropping include: insurance against complete crop failure due to pests/diseases and/or weather conditions; greater total productivity per unit of land for intercrops than for sole crops; supply of a better balanced diet for the farm family on a limited farm land area; better control of weeds and soil erosion; and avoidance of expensive labor costs during the cropping period. In spite of these advantages, the level of groundnut productivity is still very low.

One of the controversial issues requiring study is the effect on groundnuts of the N applied to cereals, and the transfer of N from groundnut to the associated cereal in situations where the farmer applies no or insufficient N fertilizer, particularly when his soil is low in organic matter content. Furthermore, the reduced nodulation and N-fixing activities of groundnut in intercropping systems would lead to a greater demand on native soil N by both the groundnut and the cereal component of the crop mixture. Because of the scarcity and high cost of N fertilizers to the small farmers, however, the productivity and fertility levels of their farms have continued to deteriorate. This is particularly aggravated by the fact that the crop residue is removed for livestock feed, fuel, and binding instead of incorporating it back into the soil.

There is a need for research on biological N-fixation, Similarly, studies are required on the choice of crop combinations and varieties, optimum sowing dates, plant arrangement/geometry in intercrops, optimum fertilizer application levels, choice of herbicides, rotation schedules, pest and disease management, and the economics of production in intercropping systems.

Sole cropping. The groundnut/cereal rotation is a common practice wherever the crop has evolved from self-sufficiency to market economy, particularly in Senegal and other northern regions of the West African cropping area. Advantages of the system are to be found in better disease and pest control, as well as in the introduction of animal-drawn tillage and specific crop husbandry, including fertilization. These factors will result in a significant increase of total land and labor productivity, in areas where fallow (a compulsory component of the traditional cropping systems) is becoming scarce. The effect of natural fallow or ploughed fallow on groundnut and cereal yields was compared with yields for the same crops grown continuously in rotation trials over several decades in Senegal, Burkina Faso, and Nigeria.

Grass fallow, essentially comprising wild grasses, can help to preserve the soil profile and slightly increase the organic matter in the soil. It limits, although it does not entirely eliminate, degradation and yield reductions in extensive cropping systems and in regions with particularly unfavorable soils and climate. However, with good soil and climatic conditions, the length of the fallow period can be reduced in accordance with the fertilizers applied, or abandoned altogether.

Of the cropping systems tested, those which prove the most profitable for the farmers, while maintaining soil fertility, are the most 'highly developed' systems, combining organic and mineral fertilizer as well as using harvest residues.

In high-risk areas (with low rainfall, very sandy soils, suscep-tible to erosion, and where repeated ploughing is not advisable), groundnut/cereal/fallow rotation is to be recommended; in more propitious areas, continuous groundnut-cereal growing can be considered.

In both cases, it is essential to maintain the organic matter content of the soil; in continuous cropping, applying only mineral fertilizer will not prevent soil acidification by cation reduction, even if it satisfies the major element requirements, and the subsequent reduction in fertility leads to reduced yields. Despite the problems posed by availability of organic matter, this factor is essential if the reproducibility of a cropping system based on alternating groundnut and cereals is to be ensured in the Sudan-Sahelian Zone.

Fertilizer studies. In West Africa, the main fertilizers applied to groundnut contain phosphorus, calcium, and sulfur.

Fertilizer studies were based on research on physiology and mineral nutrition, backed up by factorial fertilizer trials. The critical levels for N, P, K, Ca, Mg, and S were determined by leaf analysis. The contents of these elements, measured by leaf-sample analysis, provide useful information on plant nutrition and on the deficiency thresholds; in fact, this involves N × dry mass, P × N and S × N critical curves. In addition to soil analyses and field experiments, this technique made it possible to define the most cost-effective formulas for each zone, based on response and cost curves. A fertilizer map has thus been produced for Nigeria and Senegal. This has governed fertilizer application for several decades and sticks closely to local soil and climatic conditions. There is a dominant P deficiency except in the Thies region (Senegal), where phosphates are naturally abundant. Some of the fertilizer recommendations in the region are: application of soluble forms of P in the northern region; gradual incorporation of less soluble tricalcic phosphates in the central and southern regions; and correction of Mo deficiency in certain areas by mixing molybdate (30 g ha^{-1}) directly with the seed fungicide treatment or in the form of Nutramine.

In other producing countries, particularly Nigeria, the fertilizers applied on groundnut consist of combined manure (2.5 to 7.5 t ha^{-1}) and single superphosphate (60 to 100 kg ha^{-1}) applications, with a view to maintaining sufficient levels of organic matter in the soil and to correcting the major deficiencies (S and P). The current recommendation using mineral fertilizers alone requires the application of 300 kg ha^{-1} of single superphosphate and 54 kg ha^{-1} of muriate of potash before sowing.

There is a general Ca deficiency throughout much of the West African semi-arid savannah soils where empty pods or poor pod filling is a problem. Although single superphosphate and gypsum have been found to remedy the situation, it has been advocated that genetic variation can be exploited, particularly in the light sandy soils of the Sahel. Since pod size has been established as a factor influencing the Ca nutrition of pods, which is dependent on surface:volume ratio, small pods are less likely to experience Ca deficiency than large pods. Research efforts have therefore been directed at identifying varieties with desirable agronomic characters, optimum pod size, and efficient exploitation of available Ca.

Weed control. Weeds growing at the beginning of the season can have an extremely adverse effect on young groundnut plants, and adequate weeding at the right time is necessary for crop success. Early manual or mechanical weeding also makes it possible to loosen the soil and dig in the fertilizer, thus maximizing its effectiveness. This cropping technique is a significant step forward in increasing the growers' technical skills, and mechanical weeding is now widespread in major production areas (particularly in the Senegal groundnut basin and northern Nigeria).

Herbicides and formulas have also been tested successfully: Lasso® + diuron, and Cotodon® in Burkina Faso; Cotodon® + Gramoxone®, and Gesaten® in Senegal; and Igram Combi® and Dual® in Nigeria. However, the use of herbicides by farmers is limited due to lack of resources and application difficulties. This is particularly difficult in intercropping systems.

Recommended technical practices

Research organizations in various countries have made precise recommendations on the techniques developed to improve the main rainfed crops (groundnut and millet–sorghum) in Nigeria, Senegal, and other countries. Some of these recommendations are:

- Use of selected varieties;
- Seed fungicide treatment;
- Sowing in rows, at the right time, right density and right depth;
- Light mechanization using animal traction (sowing, hoeing, lifting);

- Light mineral fertilizer application, spread and dug in at the right time;
- Weeding at the right time; and
- Harvesting at the right stage of maturity.

The interaction of these techniques and the estimates of profits obtained in terms of yields (in agronomy trials) are given in Figure 1.

The wide-scale application of these techniques in Senegal during the 1960s led to a general shift from manual to mechanized agriculture, both for groundnut (which funded the shift) and for cereals grown in rotation with it. Although some of these recommendations have been adopted in other West African countries, albeit poorly, mechanization is not as widespread as in Senegal where animal traction practices have been developed.

The strategy that was adopted needed to take the minimum number of risks in a drought-prone area. It required:

- Rustic varieties, capable of withstanding difficult soils and climatic conditions;
- Low-cost, multipurpose equipment and hitched tools;
- Light fertilizers rates, based on short-term cost effectiveness; and
- Effective integration of traditional cropping practices and farming calendar.

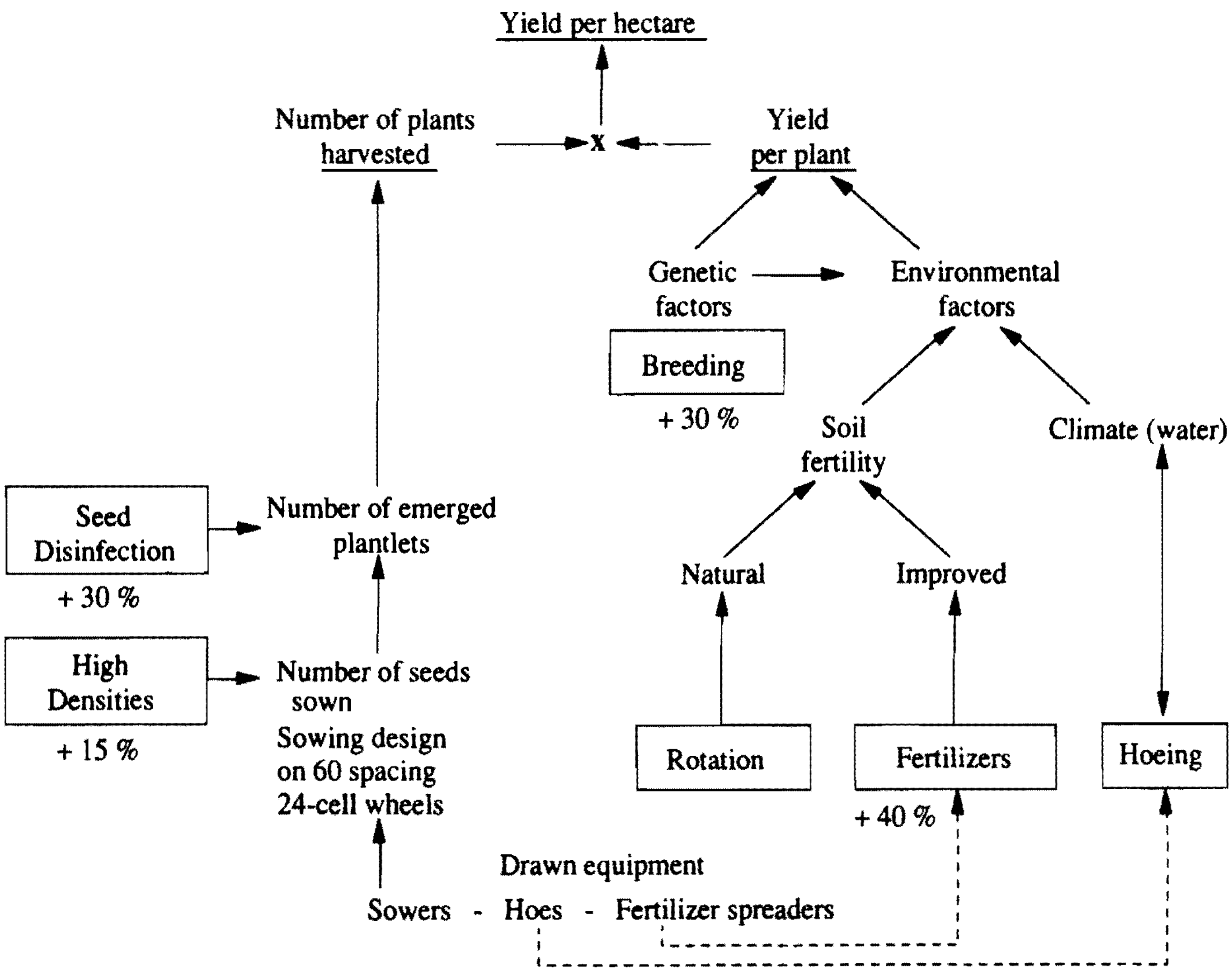


Figure 1. Principal groundnut yield factors. [Source: Propositions pour l'augmentation rapide des rendements de l'arachide au Sénégal – L'Institut de recherches pour les huiles et oleagineaux/L'Institut de recherches sul l'agronomiques tropicales et des cultures vivrieres (IRHO/IRAT), 1963.]

Crop Protection

Groundnut is attacked by numerous predators, and the damage caused is reflected in a significant fall in productivity and poorer product quality. Attacks by arthropods (insects and myriapods), worms (nematodes), and pathogens (fungi and viruses) are seen, in addition to weed competition. The phytosanitary problems in Africa are becoming more acute as crop rotation periods become shorter, the system of cropping twice a year becomes more widespread, and international seed exchanges develop. Researchers have studied these problems in terms of cropping practices, varietal improvement, and chemical and technological treatments: we shall discuss five main topics.

Emergence disease and pest protection

Numerous fungi and insects (termites, coleoptera) and myriapods (julids) attack seeds and seedlings during germination and lead to emergence losses of up to 50%. Treating seeds with fungicides + insecticides is essential, and has been studied widely. A dry coating technique has been developed and several formulas have proved their effectiveness (benomyl + captafol, captan + carbosulfan, etc.). Granox® (10% benomyl, 10% captafol, 20% carbofuran) gives excellent results in Senegal (average effect + 33% at the densities generally practiced). Until recently when they were phased out, Aldrex T® (thiram 25% + aldrin 25%) and Fernasan D® (thiram 25% + lindane 20%) were the major routine seed dressing chemicals used in Nigeria and Ghana. Apron Plus® (metalaxyl + captan + furathiocarb) and Marshal ST® (carbosulfan + thiram) are being tested under Nigerian conditions. These inexpensive but highly effective treatments are applied on a very wide scale, and products are distributed to farmers in all the areas where a specialized service provides seed supplies. The fungicide component of the treatment is by far the more important, and the hypothesis that fungi become established in wounds that already exist has been proved. Industrial coating and the distribution of ready-to-use shelled, fungicide-treated seeds is currently at the preextension stage in Senegal.

Leaf disease control

Four diseases (rosette, early and late leaf spot, and rust) have an economic impact on groundnut productivity in Africa. Disease incidence is higher the further one is to the south of the Savannah area.

Virus diseases. Rosette is a virus disease transmitted by an aphid, *Aphis craccivora*. Resistant varieties have been bred in Burkina Faso, Senegal, and Nigeria. Although the transmission mechanism and the epidemiology of the disease is fairly well understood, the way the virus acts is not yet entirely clear. Rosette can devastate harvests over vast areas if climatic conditions in a given year are propitious for early infestation; although traditional small-holders do not have access to chemical treatments (cost and application methods), the use of resistant varieties makes disease prevention possible irrespective of the circumstances. Varieties that have been extended in areas where rosette is endemic and have proved highly successful are 69-101 in Nigeria, Casamance, Guinea-Bissau, and Chad; RMP 12 and RMP 91 in Burkina Faso, Chad, and Mozambique; and SAMNUT-16 (M554.76 I) and SAMNUT-3 (M25.68) in Nigeria. ICRISAT has included them in its varietal development and international varietal trial program.

Leaf spot diseases. Leaf spot diseases (early and late) are seen in varying degrees wherever groundnut is grown. They lead to premature defoliation and yield reductions of up to 50%. Many products and formulas have been tested, but chemical control in the small-holder environment is always difficult, particularly since it is often necessary to treat against rust and leaf spot diseases at the same time. Only mancozeb (Dithane® M-45) is effective against all three diseases, but high cost and the necessary weekly application frequency rules it out for small farmers. Preventive cropping techniques limit disease incidence: alternating groundnut/cereals, early sowing, applying mineral fertilizers (particularly sulfur applications), removing haulms, and eliminating harvest residues (burying or burning).

Rust. Rust first appeared in West Africa some time after 1970, and is spreading quickly. Studies are currently concentrated on breeding resistant varieties, pathogen biology and epidemiology, and chemical treatments. Information has been obtained on how rust survives on site from one year to another, on epidemiology in relation to climatological parameters, on the host-pathogen relationship (critical infection periods in terms of yield), on methods for assessing resistance (as a back-up to breeding), on preventive agronomic methods, and on chemical control. It has been established that rust, as well as leaf spots (early and late), can be controlled with fungicides other than mancozeb. The chemicals carbendazim, tridemorph + maneb or tridemorph + MBC + maneb, which are systemic in action, require only 4–5 applications per season as opposed to 8–10 with mancozeb. Spraying of Calixin-M®, commencing at first appearance of symptoms and applied fortnightly, was also found to be effective for the control of foliar diseases in Nigeria.

Multiple disease resistance. Multiple disease resistance, which is the ultimate answer to the foliar disease problem on groundnut, is being investigated in Nigeria and Burkina Faso with some promising results. The varieties RMP 12 and RMP 91 from Burkina Faso and SAMNUT-6 from Nigeria were found to be resistant to both chlorotic and green rosette, have high yield potentials, and are resistant and moderately resistant, respectively, to early and late leaf spot diseases. The varieties MDR 8–15 ad MDR 8–19 were resistant to rosette virus in addition to rust and leaf spots.

Julid control

Studies have identified the five most harmful millipede species that cause most of the damage seen on emergence in rainfed crops and on young, not yet fully formed, groundnut pods. Three types of treatment have been developed: emergence protection, by mixing an insecticide with the product used to dust the seeds; julid poison baits spread at the time of fruiting; and soil treatment using synthetic chemicals and neem products. Only the first two have been used in some countries on edible groundnut, which is particularly susceptible and therefore makes expensive treatments a more cost-effective undertaking. The third treatment has been tried in Senegal, Niger, and Nigeria with varying degrees of success. Research is continuing on both bio-ecological data and new products. The possibility of a long-term biological control is also being considered.

Aflatoxin control

Aflatoxin, which is found in many foodstuffs, including groundnut, is thought to cause hepatic lesions, to which young stock animals are particularly susceptible. There are also strong suspicions that these substances (secreted by the fungus *Aspergillus flavus*) play a role in liver cancer etiology in man. As the toxin is eliminated when the oil is refined, only two factors pose a problem:

- Seed and seed byproducts used directly as foodstuffs, and
- Cake used as animal feed.

The conditions for groundnut contamination are known, and control methods, tried and tested in agronomic terms, have been proposed:

- Using varieties having a cycle that fits in with the rainy season;
- Using optimum sowing and harvesting dates;
- Applying recommended agronomic techniques: crop rotations, sowing densities, fertilizers, weeding, to ensure optimum physiological development;
- Harvesting and processing the most heavily contaminated pods separately (prematurely withered plants, plant snapping when pulled up);
- Applying effective insecticides and julicides; and
- Shortening the critical drying period as much as possible, and implementing early mechanical threshing as soon as it is practicable.

It goes without saying that these measures must be part of an overall plan. It would be pointless to obtain an innocuous intermediate product and then not protect it at later stages of the chain (cake, edible groundnut and byproduct manufacturing, storage, packing, and transport).

Corrective control. Corrective control is part of the industrial processing and treatment (detoxification) of products, edible groundnut, and cake to ensure that they comply with the increasingly stringent constraints imposed by the international market. Techniques have been developed for eliminating contaminated pods and seed by electronic sorting; removing the seed coat with hydrogen peroxide enables early segregation of contaminated seeds and makes sorting easier; detoxifying cake with ammonia makes it possible to obtain a safe, nitrogen-enriched product. Senegalese oil mills have applied this industrial procedure on a large scale, and detoxified Senegalese cake is now available on world markets again.

Artificial inoculation tests. Artificial inoculation tests have been developed and are used to sort varieties and hybrid progenies (programs to breed tolerant varieties).

Nematode control

Of the 47 or more nematode species that attack groundnuts in West Africa, *Helicotylenchus* sp, *Scutellonema* spp, *Tylenchorhynchus* sp, *Pratylenchus* sp, *Trichodorus* sp, and *Criconemoides* sp are the most widespread while about 13% of them have been responsible for disease situations in fields.

Nematodes that affect groundnut cause heavy pod and haulm yield losses, particularly in Gambia and the northern half of the Senegalese groundnut basin, where the problem was first detected, and probably also in most production areas. The most harmful species in Senegal was identified as *Scutellonema cavenessi* and other *Scutellonema* spp in Benin, Burkina Faso, Mali, Niger, and Nigeria. The seed testa nematode *Aphelenchoides arachidis* Bos is restricted to Nigeria. A control method was developed and applied full scale in central-northern Senegal (DBCP, 12 kg ai ha^{-1} applied as a soil treatment on 4000 ha in 1988). Pod yields increased by 500 kg ha^{-1} and haulm yields by 1000 kg ha^{-1} on average; the after-effect on the subsequent cereal crop was also positive (350 kg ha^{-1}), and the treatment has a 5-year carryover period. In Nigeria, application of Furadan® 3G at 2.5–3.0 kg ai ha^{-1} and Mocap® 10G at 6 kg ai ha^{-1} proved effective in reducing nematode populations. Research in many countries is currently concentrating on product trials (dose and application methods and residues, if any), on complementary agronomic measures (densities, ploughing, fertilization) and on implementation methods in the small-holder environment (organizing producers, credit, and socioeconomics).

Postharvest Technology

The initial aim of the groundnut postharvest technology program was to assess the industrial processing performance of new groundnut varieties developed or introduced (definition of varietal ideotypes and technological tests) to back up breeding programs. Certain aspects of groundnut quality problems quickly became research objectives, conducted in close collaboration with upstream programs, development organizations, and industrialists; current research programs are helping to develop processes to enable more effective improvement of groundnut products.

Improving groundnut technological and seed qualities

Edible groundnut has to satisfy very strict standards, some of which are specific, whereas others lead to an overall improvement of groundnut production, particularly in terms of health (aflatoxin control) and seed technology. Edible groundnut is a driving force and a test bench for the entire product range. Market and producer demands are concerned with the following:

- Shelling percentage,
- Germination capacity,
- Prevention of aflatoxin,
- Seed and pod size and shape,
- Skinning and splitting performance, and
- Organoleptic qualities after roasting.

Reliable and reproducible tests have been developed to measure the above parameters. These methods are used for varietal screening and batch quality assessment. Around 10 varieties, including 73–27 and 73–28, have been adopted as possible replacements for the edible variety GH 119–20, which is currently grown in central-southern Senegal, or to extend the crop into new areas. A few varieties were adopted for their dual oil- confectionery role (e.g., 55–437 and 73–33) and their shorter cycle, which is more suitable for dry regions.

The effect of various agronomic treatments on groundnut seed qualities has been measured; calcium spread around the plant (top-dressing) on day 40 improves pod density and size, shelling yields, seed size, exportable seed yields, and germination capacity. Application of about 25 kg ha^{-1} of boron significantly improves seed germination in many situations, particularly in the event of drought. Applying a growth regulator (daminozide) increases pod yields and the number of seeds, but also leads to a marked reduction in pod and seed size (10 to 15%). Hence, it is extremely beneficial for seed multiplication, but not for first generation exports.

Study of shelled groundnut preservation and storage methods

The bulk storage method traditionally used is not suitable for high quality products such as seed and edible groundnut. These products have to be disinfected either before or after shelling, by fumigation with methyl bromide, following well-defined instructions (dosages, number of treatments, seed moisture content, etc.) and done by an expert, then adequately packed and stored following the procedure of the edible groundnut project in Senegal. Large-scale storage in bags stacked in pyramidal shaped heaps as practiced in Nigeria requires constant fumigation and protection against rats and adverse weather conditions.

Refrigerated seed storage. Refrigerated seed storage was developed between 1970 and 1975. It enables storage over long periods (up to 2 years) with no appreciable reduction in seed germination capacity, providing that the seeds are returned gradually to ambient temperature when taken out of storage. The main aim of this method is to preserve 'emergency stocks' for dry areas. Senegal, which practices this method, currently has a capacity for 2000 t of seed. This technology is not popular in most West African countries.

Nitrogen-compensated vacuum storage. Nitrogen-compensated vacuum storage in 25 kg airtight bags, has been studied closely. Once packed, the seed can be distributed, and stored by the user, with no need for any specific precautions: the residual vacuum prevents the seeds being shaken, hence avoiding the risk of breakage and skinning due to rubbing during transport and handling. The technique, which has been tried in Nigeria and Senegal, has now gone beyond the experimental stage in Senegal where 200 t of seeds were packed and distributed in 1986.

Improving the industrial seed processing technique

Studies have been carried out at all the critical stages of the industrial process used to produce high quality seeds suitable for use as seed or for export on the edible groundnut market.

Shelling. Improvements in shelling techniques have made it possible to obtain much higher whole seed/shell yields than had previously been achieved (between 50 and 60%), by modifying standard oil mill equipment. Machine prototypes developed at Samaru, Nigeria, can shell groundnut with a whole kernel output of over 90%.

Electronic sorting. Electronic sorting specifically adapted to groundnut enables the elimination of almost all aflatoxin-contaminated seeds and imperfect seeds that are of a different color. It was adopted in Senegal for seed production and the manufacture of blanched seeds destined for roasting. This high technology is found mainly with industrial establishments.

Ready-to-use groundnut seed. Industrial production of ready- to-use groundnut seed was developed in Senegal; the shelling, sorting, coating, and packing procedures can now be totally mechanized, although there are obstacles to be surmounted before the technique can be transferred to the industrial pilot stage.

All these procedures are of prime importance, since the limited state-managed seed capital in most West African countries means that efforts will have to be made to maintain quality. At the same time, greater attention should be paid to the problems encountered by the farmer (on-farm seed production and storage).

Applying Research and Supporting Development

Researchers have often set up and managed pilot operations to confirm and apply groundnut research results. These operations have frequently expanded in the form of development projects or even national state-sector organizations, to which research is continuing to provide technical support. Highlights are given below of some major activities in West Africa.

Seed multiplication and seed plans

Research provides technical support for programming, technological production monitoring. and seed storage and packing. This support often takes the form of mixed basic seed production/adaptive research/development support operations, and has played a major role in extending new varieties and in consolidating national seed structures, particularly in Nigeria, Senegal, Niger, and Chad. In Nigeria, all agencies (government, parastatals, or private) concerned with the groundnut industry are encouraged to demonstrate active involvement in seed multiplication schemes with the National Seed Service as the starting point after the Institute of Agricultural Research at Samaru has released a variety. In ensuring availability of improved seeds, the state agricultural development agencies in each area aim at multiplying and maintaining the adopted cultivars.

In Senegal, where the varietal map has changed entirely over the past two decades, the seed production structure has made it possible to maintain the areas sown with groundnut, despite the impact of drought. The new policy in Senegal, implemented in 1985, eventually foresees seed renewal only every three years. This will mean directing research and development programs more towards helping farmers to produce and store their own seeds and towards centralized management of emergency stocks corresponding to one-third of annual requirements (around 35 000 t unshelled).

Edible groundnut operation

Under the New Agricultural Policy in Senegal, edible groundnut production management was entrusted to a specialized organization with technical support from research. An integrated structure ensures input supplies and utilization, campaign credit systems, choice of producers, producer training and crop monitoring, harvest purchases, credit recovery, organization of transport and delivery to processing mills, seed production, and packaging, and storage. The project does not benefit from any state funding or subsidies, and funds all supervisory expenditure from its own pocket. About 28 000 t were marketed in the regions of Kaolack and Fatick in 1991, and IRHO was asked to carry out a study for the setting up of a mill to process the seeds produced, with a capacity of 25 000 t, expandable to 50 000 t, including facilities for roasted-salted groundnut packing and peanut butter production.

Similar studies were carried out in Mali (confectionery groundnut packing unit at San) and Burkina Faso (engineering advisor on an industrial edible groundnut and seed equipment in Ouagadougou).

In other countries, particularly Nigeria, groundnut rehabilitation efforts are underway to involve oil millers, in support of government moves, to strengthen research and extension.

Pest control

Pests (insects, nematodes, and millipedes) have an adverse effect on groundnut and crops grown in rotation with it [millet, sorghum, and cowpea (*Vigna unguiculata*)]. Spectacular results have been obtained, in terms of pods, haulms, and seeds, using chemical treatments. A pest control project was launched in 1984, in Senegal, aimed at eradicating nematodes in the areas around Thies and Diourbel. The operation is being conducted jointly by the Research, Extension, and Crop Protection Services. Similar pest control projects have been reported in Nigeria, Niger, and Burkina Faso.

The constant interaction between mixed research and development operations and specific research programs is an integral part of the way groundnut research operates and one of the reasons for its success. It enables researchers to adapt themselves very closely to the requirements and difficulties of the rural environment, and ensures the coherence and effectiveness of the program as a whole, at all the various stages of the chain, from variety selection to industrial packaging and exports of products.

Conclusion

Although this paper has highlighted impressive research and development achievements in the groundnut industry in West Africa, there are still serious constraints to increased production that vary with the countries. Priority areas that need short and medium term attention include:

- Breeding for short-season, drought, pest, and disease resistance along with the need to strengthen and expand the existing seed multiplication schemes so as to ensure availability of improved seeds to the farmer;
- Integrated pest management strategies that are adoptable by resource-poor farmers should be developed;
- Development of appropriate technological labor-saving devices to make farmers less dependent on hired labor for sowing, weeding, and harvesting is urgently needed;
- There is the need to diagnose and study the farming systems currently used by farmers as a basis for research and development of new technologies for the farmers' use;
- Extension training needs to be boosted; and
- International cooperation and collaborative research and information exchange need to be strengthened to avoid duplication of efforts and

waste of scarce resources, particularly in areas with similar ecological conditions.

Literature Consulted

Abdullahi, A., and **Lombin, G.** 1978. Long term fertility studies at Samaru - Nigeria. 3. Comparative effectiveness of separate and combined applications of mineral fertilizers and farmyard manure in maintaining soil productivity under continuous cultivation in the Savannah. Samaru Miscellanous Paper no. 75. Samaru, Zaria, Nigeria: Institute of Agricultural Research.

Annerose, D.J. 1988. Critères physiologiques pour l'amélioration de l'adaptation à la sécheresse de l'arachide. (In Fr.) Oléagineux 43(5):217-220.

Baker, F.F., **Lombin, G.**, and **Abdullahi, A.** 1977. Long term fertility studies at Samaru. 1. Direct and residual effects of single superphosphate and farmyard manure on yields of cotton, sorghum and groundnuts grown in a rotation. Samaru Miscellaneous Paper no. 67. Samaru, Zaria, Nigeria: Institute of Agricultural Research.

Bockelée-Morvan, A. 1973. La multiplication des semences d'arachides en Afrique de l'Ouest. (In Fr.) Oléagineux 28(2):73-83.

Bockelée-Morvan, A., and **Gillier, P.** 1974. [Trial of the elimination of aflatoxin in groundnut by physical methods.] Essai d'élimination de l'aflatoxine de l'arachide par des méthodes physiques. (In Fr, En.). Oléagineux 29(11):513-516.

Carriere de Belgarric, R., and **Bour, F.** 1963. Le développement de la productivité de l'arachide au Sénégal. (In Fr.) Oléagineux 18(10):613-620.

Cattan, P., and **Schilling, R.** 1990. Les systèmes arachidiers dans les zones de savanes ouest-africaines. (In Fr.) Pages 145–171 *in* Actes des rencontres internationales "Savanes d'Afrique, terres fertiles ?" 10-14 Dec 1990, Montpellier, France. Paris, France: La Documentation Française.

Charreau, C., and **Nicou, R.** 1971. L'amélioration du profil cultural en Afrique de l'Ouest. (In Fr.) Bull. Agro. Institut de recherches agronomiques tropicales et des cultures vivrieres. IRAT no. 23.

Delbosc, G. 1968. Etude sur la régénération de la fertilité du sol dans la zone arachidière du Sénégal. (In Fr.) Oléagineux 23(1):27-33.

Gautreau, J. 1977. [Levels of intervariety leaf potentials and adaptation of the groundnut to drought in Senegal.] Niveaux de potentiels foliaires intervariétaux et adaptation de l'arachide à la secheresse au Sénégal. (In Fr. Summaries in En, Es.) Oléagineux 32(7):323-332.

Gillier, P., and **Silvestre, P.** 1969. L'arachide. (In Fr.) Paris, France: Agricultural and Forest Meteorology, Maisonneuve et Larose. 292 pp.

Khalfaoui, J.L. 1988. Approche de l'amélioration génétique de l'adaptation à la sécheresse des espèces cultivées en zone semi-aride. Application à l'arachide. (In Fr.) Thesis, Université de Paris (Paris-Sud), Orsay, France.

Lombin, G., and **Abdullahi, A.** 1977. Long term fertility studies at Samaru, Nigeria, II. Effect of farmyard manure on mono-cropped cotton, sorghum and groundnuts and a rotation of the three crops under continuous cultivation. Samaru Miscellaneous Paper no. 72. Samaru, Zaria, Nigeria: Institute of Agricultural Research.

Lombin, G., **Singh, L.**, and **Yayock, J.Y.** 1985. A decade of fertilizer research on groundnuts in the Savannah zone of Nigeria. Fertilizer Research 6:157-170.

Marenah, L.J. 1991. Groundnut research in West Africa and sustainable agriculture. Pages 56-57 *in* Summary proceedings of the Second ICRISAT Regional Groundnut Meeting for West Africa, 11-14 Sep 1990, ICRISAT Sahelian Center, Niamey, Niger. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

McDonald, D. 1978. Groundnut disease situation in northern Nigeria. Samaru, Zaria, Nigeria: Institute for Agricultural Research.

Misari, S.M., **Abraham, J.M.**, **Demski, J.W.**, **Ansa, O.A.**, **Kahn, C.W.**, **Casper, R.**, and **Breyel, E.** 1988. Aphid transmission of the viruses causing green and chlorotic rosette diseases of peanut. Plant Disease 72(3):250-253.

Misari, S.M., Boye-Goni, S., and **Kaigama, B.K.** 1990. Groundnut improvement, production, management, and utilization in Nigeria: problems and prospects. Pages 61–64 *in* Summary proceedings of the First Regional Groundnut Meeting for West Africa, 13-16 Sep 1988, ICRISAT Sahelian Center, Niamey, Niger. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Misari, S.M., Yayock, J.Y., and **Abalu, G.O.** 1982. Groundnuts: production, research, and future prospects in Nigeria. Pages 131–156 *in* Proceedings of the International Symposium in Africa on Production World Oilseeds Market and Intra-African Trade in Groundnuts and Products, 7-11 Jun 1982, Banjul, Gambia. Lagos, Nigeria: African Groundnut Council.

Picasso, C. 1987. Aflatoxine, rosette et rouille de l'arachide. Environnement climatique propice à leur présence et développement. (In Fr. Summary in En.) Oléagineux 42(1):25-33.

Picasso, C. 1987. Evolution des rendements et de ses composantes pour l'arachide et quelques cultures en rotation dans le Sud du Burkina-Faso. (In Fr. Summary in En.) Oléagineux 42(12):469-474.

Pieri, C. 1989. Fertilité des terres de savanes. (In Fr.) Paris, France: Ministère de la Coopération et du Développement, and Montpellier, France: CIRAD (Centre de coopération internationale en recherche agronomique pour le developpement).

Rouziere, A. 1986. [Storage of shelled groundnut seed in controlled atmospheres. 1. Preliminary trials 1979-1982.] Stockage des semences d'arachide décortiquées en atmosphères contrôlées. 1. Essais préliminaires 1979-1982. (In Fr. Summaries in En, Es.) Oléagineux 41(7):329-339.

Rouziere, A. 1986. [Storage of shelled groundnut seed in controlled atmospheres. 2. Pre-extension trials 1983-1985.] Stockage des semences d'arachide decortiquées en atmosphères contrôlées. 2. Essais de prévulgarisation 1983-1985. (In Fr. Summaries in En, Es.) Oléagineux 41(11):507-514.

Schilling, R. 1969. Etudes variétales sur l'arachide de bouche au Sénégal. Débouchés et perspectives. (In Fr.) Oléagineux 24(11):621-626.

Groundnut Research in the SADCC Region, 1980–1990

Z.A. Chiteka[1], D.L. Cole[2], M.J. Freire[3], Z.I. Mamba[4], H.K. Mande[5], D.J.M. Marais[6], A. Mayeux[7], S.S. Moima[8], F.F. Mwenda[9], Y.P. Rao[10], K.P. Sibuga[11], M.B. Syamasonta[12], G. Schmidt[13], G.L. Hildebrand[13], and P. Subrahmanyam[13]

Abstract

The Southern African Development Coordination Conference (SADCC) has ten member states and covers a diverse area of more than 5 million km². *Agroclimatic conditions are varied, and constraints to groundnut (*Arachis hypogaea*) production are many. Small-holder yields are low but encouraging yields have been achieved with improved production practices on research stations and on large farms.*

Groundnut is an important food crop in some SADCC countries and exportable surpluses provide valuable foreign currency earnings. These countries have relatively strong national research programs. In other countries, groundnut is a minor crop and research input has been correspondingly small. Nevertheless encouraging research progress has been made during the past decade.

- *Improved cultivars have been released in Malawi, Tanzania, Zambia, and Zimbabwe, but their adoption has been severely delayed by difficulties in achieving rapid seed multiplication.*
- *The distribution and economic importance of various diseases and insect pests of groundnut in the SADCC region has been established and research into the management of these biotic stresses is briefly reviewed.*
- *Results have confirmed the importance of early sowing for high productivity and of timely harvesting to avoid seed loss and quality deterioration. Another prerequisite for high ields is dense spacing, usually about 130 000 plants ha^{-1} for virginia cultivars and double this number for spanish cultivars. Groundnut is an excellent preceding crop for cereals. Intercropping with maize (*Zea mays*) leads to increased maize yields at the expense of groundnut productivity. Pigeonpea (*Cajanus cajan*) and sunflower (*Helianthus annuus*) are promising intercropping partners.*

This paper reviews research progress in crop improvement, protection, and cultural practices.

---

1. Groundnut Breeder, Crop Breeding Institute, Department of Research and Specialist Services, P.O. Box 8100, Causeway, Harare, Zimbabwe.
2. Senior Lecturer, Department of Crop Science, University of Zimbabwe, P.O. Box MP 167, Mount Pleasant, Zimbabwe.
3. Head, Department of Crop Production and Protection, Universidade Eduardo Mondlane, Faculty of Agronomy, C.P. 257, Maputo, Mozambique.
4. Research Officer, Malkerns Agricultural Research Station, P.O. Box 4, Malkerns, Swaziland.
5. Groundnut Breeder, Chitedze Agricultural Research Station, P.O. Box 158, Lilongwe, Malawi.
6. Senior Agricultural Researcher, Department of Agriculture and Rural Development, Ministry of Agriculture, Fisheries, Water and Rural Development, P.O. Box 788, Grootfontein, Namibia.
7. Head, Oilseed Division, Department of Agricultural Research, Sebele Research Station, Private Bag 0033, Gaborone, Botswana.
8. Program Leader and Agronomist, Agricultural Research Division, P.O. Box 829, Maseru, Lesotho.
9. Senior Groundnut Breeder, Naliendele Research Institute, P.O. Box 509, Mtwara, Tanzania.
10. Professor, Department of Crop Production, Faculty of Agriculture, University of Swaziland, P.O. Luyengo, Swaziland.
11. Head, Department of Crop Science and Production, Sokoine University of Agriculture, P.O. Box 3005, Morogoro, Tanzania.
12. Groundnut Breeder, Msekera Regional Research Station, P.O. Box 510089, Chipata, Zambia.
13. Team Leader and Principal Groundnut Agronomist, Principal Groundnut Breeder, and Principal Groundnut Pathologist, SADCC/ICRISAT Groundnut Project, Chitedze Agricultural Research Station, P.O. Box 1096, Lilongwe, Malawi.

ICRISAT Conference Paper no. CP 802.

Chiteka, A.Z., Cole, D.L., Freire, M.J., Mamba, Z.I., Mande, H.K., Marais, D.J.M., Mayeux, A., Moima, S.S., Mwenda, F.F., Rao, Y.P., Sibuga, K.P., Syamasonta, M.B., Schmidt, G., Hildebrand, G.L., and **Subrahmanyam, P.** 1992. Groundnut research in the SADCC region, 1980–1990. Pages 113–129 *in* Groundnut – a global perspective: proceedings of an international workshop, 25–29 Nov 1991, ICRISAT Center, India (Nigam, S.N., ed.). Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Résumé

Recherche arachidière dans la région de la SADCC, 1980–1990: *La Conférence de coordination du développement en Afrique australe (SADCC) a dix états membres et couvre une région très variée de plus de 5 millions de km²*. *Les conditions agroclimatiques sont variées et les contraintes subies par la production arachidière (*Arachis hypogaea*) sont nombreuses. Les rendements obtenus par des petits exploitants sont faibles, mais des rendements encourageants ont été obtenus grâce à des méthodes de production améliorées sur des stations de recherche et dans de grandes exploitations.*

L'arachide est une culture alimentaire importante dans certains pays de la SADCC et des excédents exportables fournissent des revenus en devises étrangères qui ont beaucoup de valeur. Ces pays ont des programmes de recherche nationaux relativement forts. Dans d'autres pays, l'arachide est une culture secondaire et l'intrant de recherche a été faible en conséquence. Néanmoins des programmes de recherche encourageants ont été élaborés depuis une décennie.

- *Des cultivars améliorés ont été utilisés au Malawi, en Tanzanie, en Zambie et au Zimbabwe, mais leur adoption a été gravement retardée par la difficulté d'effectuer une multiplication semencière rapide.*
- *La répartition et l'importance économique de diverses maladies et de divers insectes nuisibles qui affectent l'arachide dans la région de la SADCC ont été déterminées et des recherches sur la lutte contre ces difficultés biotiques ont été brièvement passées en revue.*
- *Les résultats ont confirmé l'importance des semis précoces pour augmenter la productivité et d'une récolte opportune pour éviter des pertes de semences et la détérioration de la qualité. Il importe d'effectuer un semis dense surtout d'environ 130 000 plants ha*$^{-1}$ *pour les cultivars virginia et du double de ce nombre pour les cultivars spanish. L'arachide est un excellent précédent cultural pour les céréales. Une culture intercalaire avec le maïs (*Zea mays*) mène à une augmentation du rendement de maïs, aux dépens de la productivité arachidière. Le pois d'Angole (*Cajanus cajan*) et le tournesol (*Helianthus annuus*) promettent d'obtenir de bons résultats comme cultures associées.*

Cette communication passe en revue les progrès de la recherche sur l'amélioration de la culture, la protection et les pratiques culturales.

The Southern African Development Coordination Conference (SADCC) has ten member states, Angola, Botswana, Lesotho, Malawi, Mozambique, Namibia, Swaziland, Tanzania, Zambia, and Zimbabwe. The area covered, 5.7 million km², varies in latitude from near the equator to 30°S, and in longitude from 11° to 41°E.

Much of the region is situated on the central African plateau where groundnuts (*Arachis hypogaea*) are grown from sea level to above 1500 m. The main areas of production are at altitudes between 900 and 1200 m.

Most of the region is characterized by unimodal summer rainfall from about mid-November to April. Rainfall varies from <300 mm of poorly distributed rainfall to well-distributed annual totals of over 1000 mm.

Groundnuts are of major importance to small-holder farmers and are the main legume in large areas of Angola, Malawi, Mozambique, Tanzania, Zambia, and Zimbabwe. They are the principal source of protein and oil but also provide a significant source of small-holder cash income. Current shortages of oil and foreign exchange have further added to their importance.

Production in the region, however, has declined in recent years. The Food and Agriculture Organization of the United Nations (FAO) estimates of area, production, and average yields of groundnut in SADCC countries are shown in Table 1.

Yields are low (400 to 700 kg ha^{-1}), in marked contrast to yields of 4000 kg ha^{-1} obtained on research stations and by large-scale commercial enterprises. There is much potential therefore for increasing small-holder yields in southern Africa.

Diseases are generally considered a major constraint in all countries except Botswana and Namibia, where low rainfall is the major limiting factor.

Lack of suitable varieties is the second major constraint. Only a few countries have long-standing groundnut breeding programs.

Table 1. Area, production, and yield of unshelled groundnuts in SADCC countries.

	Area ('000 ha)			Production ('000 ha)			Average yield (kg ha^{-1})		
Country	1979–81	1988	1989	1979–81	1988	1989	1979–81	1988	1989
Angola	40	40F[1]	40F	20	20F	20F	500	500	500
Botswana	4	12F	8F	1	3	1F	304	208	125
Lesotho					Not available				
Malawi	250	280F	281F	176	192F	193F	703	686	687
Mozambique	173	150F	150F	83	70F	70	480	467	467
Namibia					Not available				
Swaziland	2	1F	1F	1	1F	1F	484	571	571
Tanzania	91	100F	110F	54	60F	55F	591	539	500
Zambia	28	78*[2]	54*	18	38*	30	640	485	550
Zimbabwe	183	211*	210F	101	135	101	566	641	480
SADCC Region	771	872	823	454	519	651	534	512	485
Africa	6150	6006	5826	4477	4642	4602	728	773	790

1. F = FAO estimate.
2. * = unofficial figure.
Source: FAO 1990.

Crop Improvement

A major constraint in many SADCC countries is the lack of cultivars adapted to the varied agroecological requirements of the region, and the nonavailability of seed of currently recommended cultivars. Most countries experience difficulties in seed multiplication, thus the adoption by farmers of improved cultivars is unacceptably delayed. This is usually due to the inability of most countries to subsidize the cost of seed production.

There is an urgent need for cultivars adapted to limited season length caused by drought and erratic rainfall, especially in Botswana (where low night temperatures and drought stress delay maturity), Namibia, southern Tanzania, and southern Mozambique (Hildebrand 1990). Low temperatures in Lesotho extend the growth cycle of spanish cultivars beyond the duration of normal rainy seasons.

An added advantage to these cultivars would be the incorporation of seed dormancy to minimize damage from late rain.

In most other countries the need is for high-yielding good quality cultivars with resistance to early leaf spot (*Cercospora arachidicola*) and groundnut rosette. Cultivars resistant to rust (*Puccinia arachidis*) and late leaf spot (*Phaeoisariopsis personata*) are needed for Mozambique, Swaziland, and Tanzania.

Progress

Current annual groundnut production in Botswana is about 2500 t (unshelled), and is used mainly for home consumption. Groundnut is likely to be the oilseed crop best adapted to the prevailing low rainfall conditions, and the application of import parity prices as a basis for determining minimum oilseed producer prices should stimulate the production of vegetable oils. Groundnut will therefore be able to contribute significantly to the national objective of food security.

Important requirements for Botswana are early maturity and drought resistance, but cultivar improvement commenced only recently. Previous research effort concentrated on the evaluation of introduced cultivars mainly from India, Senegal, Burkina Faso, and South Africa.

Under rainfed conditions, spanish genotypes take 120–130 days to mature, and 110–120 days under irrigation (Mayeux 1985). The cultivar 55-437 (which has been very successful in West Africa) and 73-30 (a spanish type having seed dormancy) from Senegal, Flower 11, GC 8-35, and the ICRISAT selections ICGS(E) 31 and 60 have performed well. These have been superior to Sellie, but mature later than Chico (100 days). A crossing program to reduce season length has been initiated, based on backcross selection with Chico as male, and 55-437 and 73-30 as recurrent parents (Khalfaoui and Mayeux 1989). Sellie and 55-437 are included in the seed multiplication scheme (Mayeux 1985).

Botswana scientists are collaborating with Institut Senegalais de Recherches Agricoles (ISRA) scientists in Senegal in screening and breeding for drought tolerance. Populations developed from the pyramidal crossing of 8 parents are grown twice each year, alternating between Botswana and Senegal. Recurrent selection is carried out using physiological stress tests for rooting capacity and protoplasmic resistance, and field screening, as criteria for drought resistance (Khalfaoui and Mayeux 1989).

Namibia, a new SADCC member, has similar requirements to those of Botswana. ICRISAT germplasm was evaluated in northern Namibia for the first time in 1989/90.

Very little groundnut is grown in Lesotho but since the country's annual requirement of approximately 8000 t of vegetable oil has to be imported, considerable interest is being shown in groundnut production.

Early-maturing cultivars are important since low temperatures extend the growing season to as much as 190 days for spanish types. ICRISAT germplasm has shown promise and irrigated valencia groundnut trials have given yields approaching 3 t ha^{-1} (Moima 1989). However, most farmers do not have irrigation, and there seems little hope of achieving economic yields under rainfed conditions.

Malawi, one of the largest groundnut producers in the SADCC region, has for a number of years exported considerable quantities of confectionery-grade Chalimbana groundnuts, its fourth most important export crop (Ngwira 1985).

Groundnut improvement began in Malawi in the early 1960s (Ngwira 1985), and the first improved cultivar was Mwitunde from Tanzania (but not Asiriya Mwitunde) (Brown 1965). During the next 20 years six cultivars were recommended for production (Sibale 1985). Currently, the most widely grown cultivars are Chalimbana, which was introduced from Zambia, and Malimba, introduced from the Gambia (Ngwira 1985). The locally-bred rosette-resistant RG 1 was released for the Thyolo/Mulanje area (Sibale 1985), but is not widely grown. Mani Pintar and Mawanga are widely grown for oil in lake shore areas.

Emphasis in the breeding program has been placed on improvement of yield, and seed size and quality of virginia cultivars for export, and on disease resistance, particularly to early leaf spot and groundnut rosette (Sibale and Kisyombe 1980). Improvement of short-season cultivars for the drier areas of Malawi is another important requirement (Sibale 1985).

The supply of high quality Chalimbana has, however, lacked continuity in recent years (P. Brown, K.P. Foods, Rotherham, UK, personal communication, 1991). The irregular shape and size (which some say is decreasing) of Chalimbana seed makes blanching difficult and slower, resulting in increased operating costs and greater losses. It is therefore no longer favored by processors nor does it command attractive prices.

Processors demand seed of a high quality with large, uniform size and shape, and consumers demand a high content of whole nuts (cotyledons not separating during processing and packaging). Graded Chalimbana satisfies this size requirement but about two-thirds of the output is split into halves (P. Anderson, K.P. Foods, Rotherham, UK, personal communication, 1990).

Chitembana has much improved uniformity of seed size and shape and was released in 1980 for cultivation (Sibale 1985), but seed multiplication has been slow and Chitembana is yet to have an impact on Malawi exports. The ICRISAT selection, ICGMS 42, which is reported to have satisfactory processing quality, was released as CG 7 in 1990 for commercial production (Mande et al. unpublished). ACG 1 has favorable seed uniformity characteristics for the red-skin export confectionery market (Mande 1990) but has a low O/L ratio and has not been released.

Zimbabwe has similar objectives for improving export confectionery quality of virginia cultivars. However, these are grown on less than 2% of the total groundnut area (Hildebrand 1980) by commercial farmers who have irrigation (Chiteka 1990). The majority (up to 90%) of groundnut in Zimbabwe is produced as a source of food by small-holder farmers in the drier parts of the country (Chiteka 1985). These farmers need good-quality, early-maturing cultivars adapted to short rainy seasons.

Cultivar improvement began in the early 1960s (Chiteka 1985), by which time Virginia Bunch was being grown by commercial farmers. Five cultivars have been released since 1970. Makulu Red (Smartt 1978), introduced from Zambia in 1960, and Egret (Hildebrand 1975) were grown until recently but have now been replaced by Flamingo (Hildebrand 1983a), which has superior O/L ratio and seed uniformity. Although no more susceptible than Makulu Red and Egret to invasion by *Aspergillus flavus* (D.L. Cole, Department of Crop Science, University of Zimbabwe, Harare, Zimbabwe, personal communication, 1991), there is concern at high incidences of aflatoxin in deliveries of Flamingo to the Grain Marketing Board (G. Hutchison, COPA, Harare, Zimbabwe, personal communication, 1990).

Meikle (1965) reported that Natal Common had been grown by small-holder farmers in Zimbabwe for many years, but was very susceptible to early leaf spot. A number of spanish cultivars have been released over the past 20 years but few have reached the farmer because of difficulties in seed multiplication, and the "Spanish" cultivar, believed to be Natal Common, is still being grown. Plover was released in 1982 (Hildebrand 1983b) but seed has yet to be available in sufficient quantity. It is hoped that the spanish cultivar Falcon, released in 1990 (Chiteka, unpublished), will be more quickly and widely adopted.

Promising yield and early leaf spot tolerance has been recorded on new locally-bred selections (Chiteka 1989), and ICRISAT material has given promising yields but seed quality has not been sufficiently good to warrant consideration for release. ICGMS 42 has shown high yield potential in Zimbabwe.

Screening and breeding for resistance to early leaf spot, web blotch (*Didymella arachidicola*), and gray mold (*Botrytis cinerea*) is continuing. Sources of resistance to web blotch (Hildebrand 1980) and genotypes with resistance to gray mold (Chiteka 1990) have been used in the breeding program.

Late leaf spot and rust are serious in Mozambique (Malithano 1980), Swaziland (Rao and Mkhabela 1990), and southern Tanzania (Simons 1985), and resistance to these diseases is a major requirement for these countries. Rao and Mkhabela (1990) in Swaziland have identified ICRISAT germplasm lines that have acceptable yields and disease resistance. Some have also shown promise in Mozambique (Malithano et al. 1985), and in Tanzania (Simons 1985).

Groundnut is an economical crop in Mozambique but improved cultivars and cultural practices are essential to encourage increases in yield and area.

Germplasm collections were made in southern Mozambique prior to 1979, but recent collections were made in Nampula Province in the north in 1979 (Freire 1985), and in Zambezia and Cabo Delgado Provinces in 1981 (Malithano et al. 1985). A wide diversity of landraces, including all three botanical types, was collected and pedigree selections from some have resulted in improved lines, including Bebiano Branco, Bebiano Encarnado, Jonca, and Napalala, which are being recommended for production (Freire 1985). Bebiano Branco is currently undergoing purification and multiplication. RMP 12, introduced from Senegal, performed well in Nampula Province and was recommended for production (Freire 1985).

The groundnut crop in Swaziland is small, occupying only some 2% of land area (Mkhabela and Rao 1989). The groundnut area declined from 4000 ha in 1975/76 to about 1400 ha in 1982/83 and has remained at this level (Mamba and Rao, unpublished). The crop is generally considered unprofitable with yields of 500 kg ha^{-1}. Natal Common is commonly grown but Mani Pintar was never popular (Mkhabela and Rao 1989). Germplasm introduced from Zimbabwe for web blotch resistance has shown promise (Rao and Masina 1987), and ICRISAT rust and late leaf spot-resistant germplasm has performed well and has been included in national variety testing (Rao and Mkhabela 1990).

In Tanzania groundnut breeding started at Nachingwea in the late 1940s with the inception of the Groundnut Scheme but ceased with the collapse of that scheme. Red Mwitunde and Natal Common were then recommended and Red Mwitunde is still widely grown in the south (Mwenda 1985a), but in other parts of Tanzania, Dodoma Bold and Amani are also grown (Doto 1985).

Local collections in Tanzania indicate that all three botanical types are widely grown. Mani Pintar performed better than spanish types in the Ruvuma region, but elsewhere spanish and valencia types were better adapted than virginias, especially in southern Tanzania, where some virginias yielded well but pods were poorly filled (Mwenda 1985b).

A large number of accessions, including 238 local collections were evaluated at Morogoro in 1982, 1983, and 1984. A number of introductions performed consistently well, particularly Spancross, Spanhoma, Tamnut 74, and Robut 33-1, and were identified for multiplication (Reuben et al. 1985). Spancross was released as Nyota in 1983 for the Mtwara and Lindi regions (Mwenda 1985a), and was later recommended for Morogoro, Dodoma, and Iringa also (Mwenda 1985b). Robut 33-1 was released as Johari in 1985 (Mwenda 1989a). The ICRISAT spanish selections, ICGMS 2, 3, 21, and 33 (JL 24) yielded consistently well over six locations in 1985, 1986, and 1987 (Mwenda 1989b).

Makulu Red and Chalimbana have been widely grown in Zambia since the early 1960s (Sandhu 1985). Zambia's Eastern Province, the main producing area, has similar growing conditions to that of the nearby Lilongwe Plain in Malawi. Some Chalimbana is also grown in the Central Province. For a time, only Chalimbana was permitted to be grown in the Eastern

Province, but this ban was lifted in 1975 (Sandhu et al. 1985).

The remainder of Zambia has somewhat shorter rainy seasons. Here, spanish cultivars are better adapted, and make up about 15% of total production. Natal Common has been grown in these areas, mainly the Southern and Western Provinces, for many years, but Comet, which yielded consistently better (10–17%) than Natal Common (Sandhu et al. 1985), was released in 1984 (Sandhu 1985).

The objectives of cultivar improvement in Zambia are to attain self-sufficiency and to produce exportable surpluses (Sandhu 1985). In 1980, a breeding program was initiated to improve yield, quality, drought-tolerance, and resistance to early leaf spot. Local collections were undertaken in 1980, 1981, and 1982, and these were evaluated along with a number of introductions. Pure-line selection was initiated in Chalimbana and other local landraces. The introductions M 13 and Robut 33-1 performed well (Sandhu 1985).

MGS 2 (M 13) was released in Zambia in 1988 (Sandhu et al. 1989), and MGS 4 (ICGMS 42), having a 13% yield advantage over Makulu Red in 19 trials at five locations over 5 years, was approved for release in 1990. MGS 3, a cultivar with high yield potential, good quality, and an O/L ratio approaching 2.5, was approved for pre-release in 1989 (Syamasonta 1990a). MGS 3 has been included in the SADCC/ICRISAT crossing program.

ICG 7888 was identified as being the most tolerant of early leaf spot at Msekera, Zambia, while several other genotypes showed low susceptibility to the disease. Eleven germplasm accessions, including PI 350680, PI 314817, ICGMS 30, and ICG 7882, 7888, 7889, 7890, 7893, 7894, 7895, and 7896, were resistant to rust in a severe rust epidemic in 1983/84 (Kannaiyan et al. 1987). RG 1, RG 8, RG 11, RMP 12, and KIPR 19 BUS were confirmed as resistant to groundnut rosette in the severe rosette epidemic in 1982/83 (Kannaiyan et al. 1985). Some of the rust-resistant lines have been included in hybridization.

Screening groundnuts in the Northern and Northwestern Provinces of Zambia for pops tolerance has identified a few genotypes that are now being used in hybridization. These include Copperbelt Runner (a selection from TMV 1), Makulu Brown, Dixie Runner, Robut 33-1, and Comet (Syamasonta, unpublished).

Crop Protection

Diseases

Diseases are generally regarded as major constraints to groundnut production in the SADCC region. A large number of fungal, virus, nematode, and bacterial diseases have been reported. Most of the diseases are widespread, but only few are economically important on a regional basis.

Early leaf spot. Early leaf spot is the most destructive disease of groundnut in the region. The disease is widely distributed and occurs in epidemic proportions. Yield losses of up to 50% are sustained annually over wide areas (Bock 1989).

Considerable efforts have been directed at fungicidal control of early leaf spot in Malawi, Tanzania, Zambia, and Zimbabwe. Research in Zimbabwe on timing and number of applications of chlorothalonil or a mixture of benomyl and mancozeb, has led to effective management of the early leaf spot/web blotch disease complex on irrigated groundnut crops (Cole 1981). Fungicide application to rainfed groundnut is considered to be uneconomical. In Malawi, yield responses to 6–8 applications of chlorothalonil led to a recommendation recently proved to be uneconomical in on-farm yield trials (Mwenda and Cusack 1989). In recent years, strategically timed single applications of fungicides were found to be very effective and economical in Zambia (Kannaiyan et al. 1989a) and in Malawi (Hildebrand and Bock 1990). However, in Zimbabwe, a minimum of three sprays was required to improve yield significantly (Cole, unpublished).

All groundnut cultivars grown in the region are susceptible to early leaf spot, but the utilization of genetic resistance is receiving increased attention in the management of early leaf spot. Until recently, adequate resistance was not available (Bock 1989) and the lines identified as resistant to early leaf spot in other countries were found to be susceptible in Malawi. However, some recently introduced South American germplasm lines have shown a measurable level of resistance (Subrahmanyam, unpublished) and are now being utilized in the breeding program.

Severity of early leaf spot in intercropped groundnut was not markedly different from that of sole groundnut crops in Zambia (Kannaiyan et al. 1989a) or Malawi (Subrahmanyam, unpublished). Plant density did not affect disease severity in Zambia (Kannaiyan et al. 1989a). However, the effect of crop rotation on reducing disease severity was significant in Malawi (Subrahmanyam, unpublished). In Zambia, late sown crop suffered significantly less from early leaf spot than the normal sown crop (Kannaiyan et al. 1989a).

The SADCC/ICRISAT Groundnut Project is currently investigating the suitability of integrating low-input strategies including utilization of genetic resistance, single application of a suitable fungicide, and suitable agronomic practices such as crop rotation and time of sowing to lessen the risk of early leaf spot disease severity and minimize yield reduction (Subrahmanyam 1991).

Groundnut rosette. Rosette is well recognized as one of the major constraints to groundnut production in the region (Nigam and Bock 1985). Both chlorotic rosette and green rosette occur, but chlorotic rosette is the most prevalent and destructive. Although disease epidemics are sporadic, yield losses approach 100% whenever the disease occurs in epidemic proportions. Groundnut rosette is caused by a complex of three agents, groundnut rosette virus (GRV), its satellite RNA, and groundnut rosette assistor virus (GRAV) (Reddy et al. 1985).

Groundnut rosette is transmitted by aphids (*Aphis craccivora*) and can be managed very effectively by controlling the vectors using insecticides, but this practice may not be economically feasible for small-holder farmers. Information is available on the effects of early sowing and plant population on rosette disease incidence (Farrell 1976). Excellent progress has been made on utilization of genetic resistance. Effective field screening methods have been developed for large-scale evaluation of groundnut genotypes for rosette resistance (Bock 1987), and several high-yielding, agronomically acceptable groundnut genotypes (e.g., RG 1) have been bred (Nigam 1987; Chiyembekeza and Sibale 1989; Hildebrand et al. 1990).

Late leaf spot and rust. Late leaf spot and rust occur sporadically, mainly in low altitude areas (Cole 1987), but are economically important in the lake shore areas of Malawi, in coastal southern Tanzania, southern Mozambique, Swaziland, and Zambia. Fungicidal control is very effective (Simons 1985; Rao and Masina 1989) but may not be economically feasible to small-holder farmers. Evaluation of germplasm and breeding lines for resistance against rust and late leaf spot is in progress (Rao and Mkhabela 1990; Haciwa and Kannaiyan 1990; Mwenda and Mpiri 1990). Lines identified as resistant to late leaf spot and rust elsewhere (Subrahmanyam et al. 1989) were also found to be resistant when tested in the SADCC region.

Seedling diseases. Seedling diseases caused by a variety of seed and soilborne fungi (*Aspergillus niger*, *A. flavus*, *Rhizopus* spp, *Rhizoctonia solani*, *Macrophomina phaseolina*, *Pythium* spp and *Fusarium* spp) are widespread and important in almost all countries in the region. These diseases can be effectively and economically controlled by seed dressing with fungicides. Adequate information is available on the use of fungicides (e.g., thiram, captan, mancozeb, and benomyl) (Mayeux and Maphanyane 1989; Kannaiyan et al. 1989b).

Other diseases. Other diseases occur in various countries, but they are restricted in distribution and are economically important only in some areas. Web blotch (*Phoma arachidicola*) occurs in a number of countries but is only important in Zimbabwe, where it occurs mainly on long-season crops (Cole 1981), and in Swaziland (Rao 1990). Sources of resistance to web blotch have been identified in Zimbabwe (Hildebrand 1980). Gray mold occurs mainly on long-season crops in the cooler (below 20°C) and wetter areas of Zimbabwe. Benomyl is effective against this disease (Cole 1981) but has recently been superseded by procymidone (Cole, unpublished). Recently a number of genotypes with resistance to gray mold have been identified in Zimbabwe (Chiteka 1990).

Groundnut streak necrosis (GSND) is a serious disease in Malawi (Bock 1989) and Zambia (Haciwa and Kannaiyan 1990). Significant progress has been made on the etiology and ecology of GSND. The causal agent has been identified as sunflower yellow blotch virus and is transmitted by *Aphis gossypii* (Bock 1989). Peanut mottle (PMV) and tomato spotted wilt (TSWV) are commonly present on groundnut in the region but incidence is very low (Bock 1987). Other diseases that occur in the region include anthracnose (*Colletotrichum* spp), leaf scorch (*Leptosphaerulina crassiasca*), alternaria leaf blight (*Alternaria* spp), powdery mildew (*Erysiphe* spp), sclerotinia blight (*Sclerotinia* spp), stem rot (*Sclerotium rolfsii*), wilt (*Fusarium* spp), root rots (*Pythium* spp), pod rots (*Aspergillus* spp, *Rhizoctonia* spp, *Rhizopus* spp and *Fusarium* spp), bacterial wilt (*Pseudomonas solanacearum*), root knot (*Meloidogyne* spp), and witch weeds (*Alectra vogelii* and *Striga* sp).

The aflatoxin problem

Aflatoxin contamination of groundnut is a serious quality problem in the region (Cole 1991; Kannaiyan et al. 1989b). Research is currently underway on rapid detection methods for aflatoxins (Cole and Masuka 1989). Evaluation of germplasm and breeding lines identified at ICRISAT Center as having resistance to dry seed invasion by *A. flavus* and/or aflatoxin accumulation is in progress (Chiteka, unpublished).

Insect pests

Several insect pests, foliage and stem feeders (above ground) as well as root and pod feeders (below ground) cause substantial yield losses. These vary considerably between locations and seasons.

Foliage and stem feeders. Aphids, jassids (*Empoasca kerri*), and thrips (*Thrips palmi*) are important sucking pests in the region. In Zambia, yield losses from sucking pests range from 5 to 31% (Sohati and Sithanantham 1990). Aphids are important as vectors of groundnut rosette and GSND in the region. Defoliators such as *Helicoverpa* and *Spodoptera* occur sporadically and cause damage to groundnut crops in some countries of the region (Ramanaiah et al. 1989).

Use of insecticides, particularly during the preflowering period, reduced pest incidence and increased yield in Tanzania (Tarimo and Karel 1987). Recently, several groundnut genotypes with appreciable levels of resistance to foliage sucking pests (jassids) were identified (Sithanantham et al. 1990).

Soil pests. Surveys carried out during the 1986/87 crop season showed that soil pests (termites and white grubs) are important in the region (Wightman 1989; Ramanaiah et al. 1989; Chambi 1989). Termites are particularly destructive under drought conditions in Botswana (Wightman 1989). Carbofuran effectively controls termites in Botswana, but costs of US$ 70 ha^{-1} may not be economical because of low yield potential (Mayeux, unpublished). In Zambia, yield losses from soil pests were estimated at 2–19% (Sohati and Sithanantham 1990). White grubs are destructive in sandy soils of Zimbabwe and Malawi. *Hilda patruelis*, often associated with cashew cultivation, is of localized importance in coastal Tanzania and Mozambique. It is also serious in parts of Malawi and in Zimbabwe, particularly on irrigated crops, where band-spraying of the perimeters of fields has prevented the spread of the pest. Millipedes (although not insects) cause serious pod damage in some parts of the region. False wireworms frequently attack developing pods and have reduced yield by 20–30% in some years in Mozambique (Ramanaiah et al. 1989).

Future research needs

- The occurrence and distribution of various diseases, insects and other pests of groundnut need to be determined through systematic surveys in the region. The available information on groundnut diseases and pests from Botswana, Lesotho, Namibia, and Angola is inadequate.
- The extent of survival and carry-over of the early leaf spot pathogen in infected crop debris needs to be studied. The role of various environmental factors on early leaf spot development and the occurrence and distribution of pathotypes of early leaf spot pathogen need to be determined.
- Identification of sources of stable resistance to early leaf spot and their utilization in breeding programs should be given high priority.
- The occurrence and severity of groundnut rosette in the SADCC region fluctuates constantly and the reasons for these fluctuations are not fully elucidated. Serological techniques for detecting groundnut rosette viruses are necessary to undertake studies on disease epidemiology. The sources of resistance to rosette available so far originated from the frontier region between Burkina Faso and Côte d'Ivoire in West Africa and represent only a narrow genetic base. There is a need for new sources of resistance to broaden the genetic base of resistance to this disease.
- The levels of aflatoxin contamination in various countries in the region need to be determined. The status of soil pests in relation to aflatoxin contamination needs elucidation. There is a need to educate farmers in simple agronomic and cultural practices that are useful in reducing aflatoxin contamination.

- There is a need for clarification of species composition of various insect pests especially jassids, thrips, and white grubs.

Cultural Practices

Research efforts during the last decade were concentrated on variety improvement with regard to yield, confectionery quality, and disease resistance.

In the major groundnut-producing SADCC countries, most of the favorable cultural practices had been the subject of numerous investigations and were well established before 1980. As usual in the case of agronomy research, the results generally applied to specific soils, climates, and cultivars.

Research on cultural practices has been carried out almost exclusively by national agricultural research teams. The Regional Project only recently initiated one cropping systems trial and continues to prefer to support national agronomy research rather than to get involved in an extensive program of its own that would be limited to few locations.

Sowing and harvesting dates

Results obtained during the last decade confirmed that sowing as early as possible in the season, either with irrigation or after the first good rains, is advantageous (Shumba 1983; Kelly 1985; Sibuga et al. 1990). Virginia-type cultivars seem to be more sensitive in this respect than spanish ones. Delayed sowing may lead to increased rosette virus incidence and early leaf spot severity (Taylor 1985).

Insufficient labor or competition for labor by subsistence cereal crops such as maize, with a coinciding optimal sowing period, often prevents farmers from timely sowing. Kelly (1985) and Sibuga et al. (1990) therefore suggested sowing before the first rains into dry soil. The disadvantage of an eventually irregular emergence was considered to be less important than that of delayed sowing. According to Reddy et al. (1987), groundnut in the Msekera and Masumba areas of Zambia should not be sown beyond the third week in December.

Not only early sowing but also timely harvesting is important to secure high groundnut yield and quality. After maturity, plants steadily disintegrate so that pod recovery becomes difficult and pod rot may occur. In Tanzanian trials, losses were more important in the case of an early spanish cultivar than in that of a late virginia one. The first tended to germinate, while the last was affected by insect pests, especially termites. Timely harvesting is also very important to reduce fungal invasion and aflatoxin contamination (Kafiriti 1990).

Land preparation and sowing depth

Mayeux and Maphanyane (1989) found that mounding of spanish-type groundnut during the first weeding operation had a deleterious effect on pod yield and harvest quality. According to Rweyemamu and Boma (1990) furrow seedbeds may be disadvantageous in moist seasons and ridge sowing disadvantageous under dry conditions, whereas flat seedbeds seem to provide favorable growing conditions in the majority of cases.

Freire and Ramanaiah (1990) studied the effects of sowing depth and compaction on groundnut density and productivity. On an irrigated loam, sowing depths between 2 cm and 15 cm hardly influenced the plant densities at 13, 42, and 133 days after sowing. Compaction by human foot or car tire accelerated plant establishment and led to increased yield. On the other hand, on initially irrigated sandy soil, sowing at 2 cm depth was followed by reduced plant population, and sowing at 15 cm depth led to delayed plant establishment. However, yield did not differ markedly, and compaction appeared to have no noticeable effect.

In Zimbabwe, sowing depths between 5.0 and 7.5 cm are recommended (COPA 1989).

Weeding

Weed competition is considered to be most detrimental to groundnut productivity. According to Sibuga et al. (1989), weeds hardly influenced groundnut yields when the plots were weeded 2 and/or 4 weeks after groundnut emergence. On the other hand, weed infestation beyond the first 6 weeks led to drastically reduced yield.

In Zambia, weeding twice, at 25 and 60 days after sowing, led to appreciably higher yields than the traditional single weeding at 50 days after sowing (J.C. Musanya, Msekera Regional Research Station, Zambia, personal communication 1991).

At the Chitedze Research Station in Malawi (Mande, unpublished) the period from 35 to 45 days after emergence (DAE) appeared to be critical for groundnut productivity. When weed pressure was low, one hoeing at 40 DAE gave the same results as three weedings, two at 15 and 30 DAE and the last at 70 DAE when big weeds were pulled out. However, the three weedings were superior to the single weeding when weed pressure was high.

Plant density

Available results indicate that groundnut is able to compensate for low density to a considerable extent by increased plant yield, so that yields obtained with a wide range of densities may differ only slightly. However, numerous results are in favor of dense spacing with optimum densities of about 90 000 to 130 000 plants ha^{-1} for virginia runner type and about 130 000 to 180 000 plants ha^{-1} for spanish or bunch-type cultivars. In order to ensure sufficiently high plant populations, Ngwira (1985) and Maliro (1989) favored a 60-cm distance between rows instead of 90 cm as previously recommended in Malawi. J.C. Musanya (Msekera Regional Research Station, Zambia, personal communication, 1991) recommended 75 cm ridges and within ridge spacings of 15 cm for virginia and 10 cm for spanish-type cultivars.

Taking into consideration the multitude of available results, it seems that the number of plants ha^{-1} is the most important factor determining the productivity unit $area^{-1}$. Row spacings of up to about 100 cm seemed to have little effect (Reddy et al. 1987; Reddy et al. 1989).

Taylor (1985) found a yield increase in virginia cultivars up to about 130 000 plants ha^{-1} and in spanish cultivars up to 250 000 plants ha^{-1}. Tarimo and Msekele (1987) reported a linear yield increase with increasing plant density up to 400 000 plants ha^{-1}.

In Zimbabwe, between 125 000 and 150 000 plants ha^{-1} are recommended for virginia and double these populations for spanish cultivars. Row spacing of 45 cm ensured maximum yield (COPA 1989).

In a very dry season on sandy soil at Sebele, Botswana, yields of a spanish cultivar were highest at a target density of 166 000 plants ha^{-1} and lowest at 37 000 or 66 000 plants ha^{-1}. At low density, seed quality was improved and seed requirement reduced. Very low density led to prolonged flowering, uneven maturity, and low shelling percentage (Mayeux and Maphanyane 1989). After 4 years of study, Mayeux (unpublished) recommended plant populations between 75 000 and 100 000 ha^{-1}, i.e., considerably lower ones than the optimal densities for spanish-type cultivars in higher rainfall areas.

Fertilizer response

A response to N fertilizer is unlikely to occur and a response to P and K fertilizer will depend on the soil nutrient status or applications to previous crops. Normally, cereals are more responsive to fertilizers and thus allow a quick return of fertilizer expenditures, whereas groundnut may thrive well on residual P, K, or S. Fertilizer P is absorbed to only a limited extent by a crop and would be largely available to groundnut following in the next season.

Results from various SADCC countries, obtained mostly on experiment stations or state farms, showed no, or only erratic, responses to P, K, S, or Ca (lime) application (Ramanaiah et al. 1985; Dendere 1987; Mayeux and Maphanyane 1989; Reddy et al. 1989).

On the other hand, Shumba (1983) reported that light applications of P fertilizer increased groundnut yields on depleted sandveld soils of Zimbabwe. Ramanaiah et al. (1985) found high responses to P fertilizer on coarse sand on farmers' fields in the coastal area of Mozambique. According to Taylor (1985), groundnut in southeastern Tanzania responded well to P fertilizer application up to 21.8 kg P ha^{-1}. Dendere (1987) reported a moderate response to P fertilizer, limited to a few sites in Zimbabwe. At Morogoro, Tanzania, both triple superphosphate and rock phosphate showed positive effects on groundnut (Rweyemamu and Nyanda 1990).

Mayeux (unpublished) found in two seasons on slightly acid sandy soil that gypsum application (500 kg ha^{-1}) led to increased groundnut yield and was also a prerequisite for N, P, and K fertilizer efficiency. Whether this effect was due to Ca or S is being investigated.

It can be concluded that in cases of acute P, K, S, or Ca deficiency, the application of fertilizers containing these nutrients will be a prerequisite for successful groundnut cultivation.

In a paper on pops research in Zambia, Syamasonta (1990b) summarized research carried out before 1980. He advocated pops resistance screening as a cheaper and more effective alternative to liming. Pops incidence is high on acid soils (pH 4.5 and below) in several countries.

Intercropping and crop rotation

Small-holder farmers partly tend to intercrop groundnut with other crops, predominantly maize or sorghum (*Sorghum bicolor*). Most experiments on intercropping allowed single season comparisons of either sole crops with intercropping combinations or of various intercropping treatments. However, the only acceptable alternative to continued intercropping is crop rotation.

Results of intercropping experiments vary greatly depending not only on environmental conditions (weather, soil) but also on details of the cropping system. In spite of the complexity of this subject, only a few contributions have been made during the last decade.

Several researchers found that maize-groundnut intercropping was not consistently advantageous as compared with sole cultivation or rotation of the two partners, or obtained erratic results (Ramanaiah et al. 1987; Reddy et al. 1989; Kafiriti and Chambi 1989; Rwamugira and Massawe 1990).

A few maize-groundnut combinations showed positive intercropping effects: Reddy et al. (1987) found in 1982/83 at Msekera, Zambia, that maize at full sole crop density, intercropped on same ridges with groundnut at full density, led to a 22% intercropping advantage, in that maize yields were not reduced but the additional groundnut production amounted to 20% of a respective sole crop yield. Reddy et al. (1989) reported 1985/86 results obtained with different row arrangements of maize and groundnut (1:1 and 1:2) at various maize and groundnut densities. Groundnut LER varied between 0.20 and 0.47 (average of 10 combinations 0.28). Maize results were not revealed, but the authors mentioned a maximum intercropping advantage of 21% at full maize plus full groundnut density plus additional fertilizer application to maize.

There are other crops that are more promising intercropping partners for groundnut than maize or sorghum. In a trial including maize, sorghum, cotton (*Gossypium* spp), sunflower, and pigeonpea as partner crops of groundnut, a 1:1 combination with sunflower gave the greatest advantage, followed by a 1:1 combination with pigeonpea, and a 1:1 combination with cotton. Groundnut LER were high in the case of sunflower (0.86) and pigeonpea (0.78), but low in combinations of 1 groundnut : 2 maize or sorghum plants (0.30 and 0.35, respectively) (Reddy et al. 1989).

At the Sokoine University farm in Tanzania, paired rows of groundnut alternating with single maize rows gave higher groundnut yields (+29%) than alternating single rows of both crops (+5%) over the control. The greater area allocated to groundnut in the first case (+25%) should, however, be taken into account. Groundnut LER were 0.6 and 0.4 and total LER 1.3 and 1.0, under the two systems (Rwamugira and Massawe 1990). Maize yields were not revealed, but this crop may have benefitted most from the paired groundnut rows.

In a combined intercropping and crop rotation trial at the Chitedze Research Station, Schmidt (unpublished) replaced every other maize plant within rows by two groundnut plants of virginia-type or three of spanish-type cultivars. Sole crop maize yields were high (10.6 t ha^{-1} at 55 000 plants ha^{-1}), but intercropping still led to a considerable increase in maize yields $plant^{-1}$ (about 30%, LER 0.65). On the other hand, intercropping led to low groundnut yields (LER of four cultivars ranging between 0.23–0.35). The corresponding total LER ranged between 0.90 and 0.97.

There was an interaction between groundnut cultivars and cropping systems with regard to seed yields, indicating differences among groundnut cultivars in suitability for intercropping. ICGV-SM 85038 appeared to be particularly resistant to maize aggressiveness, but ICGMS 42, in spite of its drastic yield reduction by intercropping, still gave a yield similar to ICGV-SM 85038.

On this fertile loam, maize yields in the subsequent season (average 10.5 t ha^{-1}) were slightly higher after sole groundnut than after maize-groundnut intercropping, but, in general, the effects of the preceding crops on the test crop were not appreciable, although nitrogen fertilizer had not been applied to the latter. On the other hand, M. Natarajan (Department of Research and Specialist Services, Zimbabwe, personal communica-tion 1991) found on two sites with sandy soil that maize not supplied with N fertilizer gave considerably higher yields when preceded by groundnut than when maize preceded. The advantage was equivalent to that of about 30 kg N^{-1} applied to maize.

Acknowledgments

The authors wish to thank their colleagues in the various national programs for their contributions and assistance in the preparation and coordination of this review.

References

Bock, K.R. 1987. Rosette and early leaf spot diseases: a review of research progress, 1984/85. Pages 5–14 *in* Proceedings of the Second Regional Groundnut Workshop for Southern Africa, Harare, Zimbabwe, 10–14 Feb 1986, Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Bock, K.R. 1989. ICRISAT regional groundnut pathology program: a review of research progress during 1985–87 with special reference to groundnut streak necrosis disease. Pages 13–20 *in* Proceedings of the Third Regional Groundnut Workshop, 13–18 Mar 1988, Lilongwe, Malawi. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Brown, P. 1965. Review of groundnut experiments in Malawi. Rhodesian Journal of Agricultural Research 3:39-50.

Chambi, J.Y. 1989. Groundnut improvement program in Tanzania: problems and research objectives. Pages 169–172 *in* Proceedings of the Third Regional Groundnut Workshop for Southern Africa, 13–18 Mar 1988, Lilongwe, Malawi. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Chiteka, Z.A. 1985. The present and future status of groundnut breeding and research in Zimbabwe. Pages 125–133 *in* Proceedings of the Regional Groundnut Workshop for Southern Africa, 26–29 Mar 1984, Lilongwe, Malawi. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Chiteka, Z.A. 1989. Report on the highlights of results of groundnut trials in the Zimbabwe groundnut breeding program 1987/88. Presented at the Second SADCC Groundnut Breeders and Agronomists Meeting, 13–16 Mar 1989. Lilongwe, Malawi.

Chiteka, Z.A. 1990. Resistance to Botrytis gray mold in some groundnut genotypes in Zimbabwe. Pages 105–109 *in* Proceedings of the Fourth Regional Groundnut Workshop for Southern Africa, 19–23 Mar 1990, Arusha, Tanzania. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Chiyembekeza, A.J., and **Sibale, P.K.** 1989. Suitability of Malawi groundnut cultivars for the confectionery market. Pages 77–81 *in* Proceedings of the Third Regional Groundnut Workshop for Southern Africa, 13–18 Mar 1988, Lilongwe, Malawi. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Cole, D.L. 1981. Diseases of groundnuts (*Arachis hypogaea* L.). 1. Fungicide spray effects on *Cercospora arachidicola* and *Phoma arachidicola* leaf infection, kernel yield and pod rots. Zimbabwe Journal of Agricultural Research 19:101-110.

Cole, D.L. 1987. Rust disease of groundnut in southern Africa: present situation and possible interactions with other groundnut foliar diseases. Pages 109-114 *in* Groundnut rust disease: proceedings of a Discussion Group Meeting, 24-28 Sep 1984, ICRISAT Center, India. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Cole, D.L. 1991. The prevalence of aflatoxins in groundnuts in Zimbabwe. Pages 56–61 *in* Proceedings of the Second Regional Groundnut Plant Protection Group Tour, 25 Feb–1 Mar 1991, Zimbabwe, Mozambique, Swaziland. Lilongwe, Malawi: SADCC (Southern African Development Coordination Conference)/ICRISAT (International Crops Research Institute for the Semi–Arid Tropics) Groundnut Project. (Limited distribution.)

Cole, D.L., and **Masuka, A.J.** 1989. Evaluation of new rapid methods for aflatoxin detection in groundnuts in Zimbabwe. Pages 185–189 *in* Proceedings of the Third Regional Groundnut Workshop for Southern Africa, 13–18 Mar 1988, Lilongwe, Malawi. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

COPA (Commercial Oilseeds Producers' Association). 1989. Groundnuts in Zimbabwe. Section 5. Planting. Pages 13–15 *in* Oilseeds Handbook. 3rd edn. Harare, Zimbabwe: COPA.

Dendere, S. 1987. Constraints to groundnut production and research priorities for communal areas in Zimbabwe. Pages 125–129 *in* Proceedings of the Second Regional Groundnut Workshop for Southern Africa, 10–14 Feb 1986, Harare, Zimbabwe. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Doto, A.L. 1985. Groundnut improvement in Tanzania: progress and future orientation. Pages 103–105 *in* Proceedings of the Regional Groundnut Workshop for Southern Africa, 26–29 Mar 1984, Lilongwe, Malawi. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

FAO (Food and Agriculture Organization of the United Nations). 1990. 1989 Production Yearbook, vol. 43. Rome, Italy: FAO.

Farrell, J.A.K. 1976. Effects of groundnut sowing date and plant spacing on rosette virus disease in Malawi. Bulletin of Entomological Research 66:159–171.

Freire, M.J. 1985. Mozambique groundnut improvement project. Pages 25-26 *in* Proceedings of the Regional Groundnut Breeders Group Tour, 25 Feb–1 Mar 1985, Zimbabwe, Zambia, Malawi. Lilongwe, Malawi: International Crops Research Institute for the Semi-Arid Tropics, Regional Groundnut Program for Southern Africa. (Limited distribution.)

Freire, M.J., and **Ramanaiah, K.V.** 1990. Some factors influencing plant density and yield of groundnut. Pages 177–181 *in* Proceedings of the Fourth Regional Groundnut Workshop for Southern Africa, 19–23 Mar 1990, Arusha, Tanzania. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Haciwa, C.H., and **Kannaiyan, J.** 1990. Prevalence of groundnut diseases and extent of yield losses due to leaf spot diseases in Zambia. Pages 93–97 *in* Proceedings of the Fourth Regional Groundnut Workshop for Southern Africa, 19–23 Mar 1990, Arusha, Tanzania. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Hildebrand, G.L. 1975. Egret groundnut – crop variety release notice. Rhodesia Agricultural Journal 72:154.

Hildebrand, G.L. 1980. Groundnut production, utilization, research problems and further research needs in Zimbabwe. Pages 290–296 *in* Proceedings of the International Workshop on Groundnuts, 13–17 Oct 1980, ICRISAT Center, India. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Hildebrand, G.L. 1983a. "Flamingo" groundnut – crop variety release notice. Zimbabwe Agricultural Journal 80:115–116.

Hildebrand, G.L. 1983b. "Plover" groundnut – crop variety release notice. Zimbabwe Agricultural Journal 80:116–117.

Hildebrand, G.L. 1990. Recent results with early-maturing groundnut genotypes. Pages 9–13 *in* Proceedings of the Fourth Regional Groundnut Workshop for Southern Africa, 19–23 Mar 1990, Arusha, Tanzania. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Hildebrand, G.L., and **Bock, K.R.** 1990. Effect of timing of single applications of fungicide on groundnut yield. Pages 3–7 *in* Proceedings of the Fourth Regional Groundnut Workshop for Southern Africa, 19–23 Mar 1990, Arusha, Tanzania. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Hildebrand, G.L., **Bock, K.R.**, and **Nigam, S.N.** 1990. Groundnut rosette virus: recent research progress in southern Africa. Presented at Workshop on Groundnut Virus Diseases in Africa, 18–19 Sep 1990, Montpellier, France.

Kafiriti, E.M. 1990. Groundnut agronomy in Tanzania: the importance of timely harvesting of groundnut. Pages 189–193 *in* Proceedings of the Fourth Regional Groundnut Workshop for Southern Africa, 19–23 Mar 1990, Arusha, Tanzania. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Kafiriti, E.M., and **Chambi, J.Y.** 1989. Groundnut based intercropping systems. Presented at the Second SADCC Groundnut Breeders and Agronomists Meeting, 13–16 Mar 1989, Lilongwe, Malawi.

Kannaiyan, J., **Haciwa, C.H.**, **Kelly, G.S.**, and **Sandhu, R.S.** 1985. Studies on groundnut rosette in Zambia. ICRISAT Regional Groundnut News (Chitedze, Malawi) 2:70–71.

Kannaiyan, J., **Sandhu, R.S.**, and **Haciwa, C.H.** 1987. Recent developments in groundnut pathology research in Zambia. Pages 51–56 *in* Proceedings of the Second Regional Groundnut Workshop for Southern Africa, 10–14 Feb 1986, Harare, Zimbabwe. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Kannaiyan, J., Sandhu, R.S., Haciwa, C.H., and **Reddy, M.S.** 1989a. Management of leaf spots of groundnut in Zambia. Pages 35–41 *in* Proceedings of the Third Regional Groundnut Workshop for Southern Africa, 13–18 Mar 1988, Lilongwe, Malawi. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Kannaiyan, J., Sandhu, R.S., and **Phiri, A.L.** 1989b. Aflatoxin and *Aspergillus flavus* contamination problems of groundnuts in Zambia. Pages 65–70 *in* Aflatoxin contamination of groundnuts: proceedings of the International Workshop, 6–9 Oct 1987, ICRISAT Center, India. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Kelly, G. 1985. A review of agronomic work in Zambia, and prospects for the future. Pages 115–118 *in* Proceedings of the Regional Groundnut Workshop for Southern Africa, 26–29 Mar 1984, Lilongwe, Malawi. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Khalfaoui, J.L., and **Mayeux, A.** 1989. Groundnut selection with respect to climatic constraints in Botswana. Presented at the Second SADCC Groundnut Breeders and Agronomists Meeting, 13–16 Mar 1989, Lilongwe, Malawi.

Maliro, C.E. 1989. Effect of ridge spacing and plant population on groundnut yield in Malawi. Pages 205–209 *in* Proceedings of the Third Regional Groundnut Workshop for Southern Africa, 13–18 Mar 1988, Lilongwe, Malawi. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Malithano, A.D. 1980. Groundnut production, utilization, research problems and further research needs in Mozambique. Pages 257–261 *in* Proceedings of the International Workshop on Groundnuts, 13–17 Oct 1980, ICRISAT Center, India. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Malithano, A.D., Ramanaiah, K.V., and **Chilengue, B.S.** 1985. Local and exotic groundnut germplasm collection and evaluation. Pages 71–79 *in* Proceedings of the Regional Groundnut Workshop for Southern Africa, 26–29 Mar 1984, Lilongwe, Malawi. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Mande, H.K. 1990. Groundnut breeding program in Malawi. Pages 41–44 in Proceedings of the Fourth Regional Groundnut Workshop for Southern Africa, 19–23 Mar 1990, Arusha, Tanzania. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Mayeux, A. 1985. Report on groundnut research in Botswana for the 1984/85 season. ICRISAT Regional Groundnut News (Chitedze, Malawi) 2:25–39.

Mayeux, A., and **Maphanyane, G.S.** 1989. Groundnut research under low-rainfall conditions in Botswana. Pages 149–155 *in* Proceedings of the Third Regional Groundnut Workshop for Southern Africa, 13–18 Mar 1988, Lilongwe, Malawi. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Meikle, J.O. 1965. A survey of African-grown groundnut varieties in Rhodesia. Rhodesia Agricultural Journal 62:109–113.

Mkhabela, M.S., and **Rao, Y.P.** 1989. Groundnut (*Arachis hypogaea* L.) research in Swaziland: past, present and future. Presented at the Second SADCC Groundnut Breeders and Agronomists Meeting, 13–16 Mar 1989, Lilongwe, Malawi.

Moima, S.S. 1989. Groundnut improvement program in Lesotho: research priorities, problems and future strategies. Presented at the Second SADCC Groundnut Breeders and Agronomists Meeting, 13–16 Mar 1989, Lilongwe, Malawi.

Mwenda, F.F. 1985a. Groundnut breeding and improvement programs in Tanzania. Pages 81–87 *in* Proceedings of the Regional Groundnut Workshop for Southern Africa, 26–29 Mar 1984, Lilongwe, Malawi. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Mwenda, F.F. 1985b. Groundnut breeding in south eastern Tanzania. Pages 16–24 *in* Proceedings of the Regional Groundnut Breeders Group Tour, 25 Feb–1 Mar 1985, Zimbabwe, Zambia, Malawi. Lilongwe, Malawi: International Crops Research Institute for the Semi-Arid Tropics, Regional Groundnut Program for Southern Africa. (Limited distribution.)

Mwenda, F.F. 1989a. Groundnut breeding in Tanzania: present approach and future projections. Pages 93–97 *in* Proceedings of the Third Regional Groundnut Workshop for Southern Africa, 13–18 Mar 1988, Lilongwe, Malawi. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Mwenda, F.F. 1989b. The performance of ICGMS lines in the SADCC/ICRISAT regional yield trials and their impact on the national breeding program at Naliendele, Mtwara, Tanzania. Presented at the Second SADCC Groundnut Breeders and Agronomists Meeting, 13–16 Mar 1989, Lilongwe, Malawi.

Mwenda, A.R.E., and **Cusack, T.J.** 1989. An economic evaluation of small-holder farmers' use of the fungicide chlorothalonil (Daconil® 2787 W-75) on groundnuts in Lilongwe Agricultural Development Division, Malawi. Pages 65–73 *in* Proceedings of the Third Regional Groundnut Workshop for Southern Africa, 13–18 Mar 1988, Lilongwe, Malawi. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Mwenda, F.F., and **Mpiri, M.G.** 1990. Performance of recently released commercial groundnut cultivars in Tanzania. Pages 51–54 *in* Proceedings of the Fourth Regional Groundnut Workshop for Southern Africa, 19–23 Mar 1990, Arusha, Tanzania. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Ngwira, P. 1985. Groundnut improvement in Malawi. Pages 49–53 *in* Proceedings of the Regional Groundnut Workshop for Southern Africa, 26–29 Mar 1984, Lilongwe, Malawi. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Nigam, S.N. 1987. A review of the present status of the genetic resources of the ICRISAT Regional Groundnut Improvement Program, of the southern African cooperative regional yield trials, and of rosette virus resistance breeding. Pages 15–30 *in* Proceedings of the Second Regional Groundnut Workshop for Southern Africa, 10–14 Feb 1986, Harare, Zimbabwe. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Nigam, S.N., and **Bock, K.R.** 1985. A regional approach to groundnut improvement. Pages 33–42 *in* Proceedings of the Regional Groundnut Workshop for Southern Africa, 26–29 Mar 1984, Lilongwe, Malawi. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Ramanaiah, K.V., Malithano, A.D., and **Chilengue, B.S.** 1985. Effect of fertilizers on the yield of groundnut in Mozambique. Pages 67–69 *in* Proceedings of the Regional Groundnut Workshop for Southern Africa, 26–29 Mar 1984, Lilongwe, Malawi. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Ramanaiah, K.V., Malithano, A.D., and **Freire, M.J.** 1987. Groundnut/maize intercropping in Mozambique. Pages 119–121 *in* Proceedings of the Second Regional Groundnut Workshop for Southern Africa, 10–14 Feb 1986, Harare, Zimbabwe. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Ramanaiah, K.V., Freire, M.J., Chilengue, B.S., and **Munguambe, A.V.** 1989. Research on groundnuts in Mozambique. Pages 157–161 *in* Proceedings of the Third Regional Groundnut Workshop for Southern Africa, 13–18 Mar 1988, Lilongwe, Malawi. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Rao, Y.P. 1990. Regional screening for late leaf spot and rust resistance of groundnut in Swaziland. Pages 23–24 *in* Proceedings of the Fourth Regional Groundnut Workshop for Southern Africa, 19–23 Mar 1990, Arusha, Tanzania. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Rao, Y.P., and **Masina, G.T.** 1987. Groundnut production and research in Swaziland. Pages 73–76 *in* Proceedings of the Second Regional Groundnut Workshop for Southern Africa, 10–14 Feb 1986, Harare, Zimbabwe. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Rao, Y.P., and **Masina, G.T.** 1989. Recent groundnut research in Swaziland. Pages 163–167 *in* Proceedings of the Third Regional Groundnut Workshop for Southern Africa, 13–18 Mar 1988, Lilongwe, Malawi. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Rao, Y.P., and **Mkhabela, M.S.** 1990. Groundnut research in Swaziland: the 1988/89 cropping season. Pages 27–31 *in* Proceedings of the Fourth Regional Groundnut Workshop for Southern Africa, 19–23 Mar 1990, Arusha, Tanzania. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Reddy, D.V.R., Murant, A.F., Duncan, G.H., Ansa, O.A., Demski, J.W., and **Kuhn, C.W.** 1985. Viruses associated with chlorotic rosette and green rosette diseases of groundnut in Nigeria. Annals of Applied Biology 107:57–64.

Reddy, M.S., Kelly, G., and **Musanya, J.C.** 1987. Recent agronomic developments in groundnut investigations in Zambia. Pages 57–64 *in* Proceedings of the Second Regional Groundnut Workshop for Southern Africa, 10–14 Feb 1986, Harare, Zimbabwe. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Reddy, M.S., Kanenga, K., Musanya, J.C., and **Kelly, G.** 1989. Recent developments in agronomic research in Zambia, 1985–87. Pages 197–204 *in* Proceedings of the Third Regional Groundnut Workshop for Southern Africa, 13–18 Mar 1988, Lilongwe, Malawi. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Reuben, S.O.W.M., Keswani, C.L., and **Doto, A.L.** 1985. Groundnut research at Morogoro. ICRISAT Regional Groundnut News (Chitedze, Malawi) 2:59–64.

Rwamugira, W.P., and **Massawe, R.D.** 1990. Groundnut/maize intercrop: effect of spatial arrangement on yield and its components. Pages 149–153 *in* Proceedings of the Fourth Regional Groundnut Workshop for Southern Africa, 19–23 Mar 1990, Arusha, Tanzania. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Rweyemamu, C.L., and **Boma, F.B.** 1990. Response of four groundnut genotypes to three seedbed types at Morogoro, Tanzania. Pages 161–165 *in* Proceedings of the Fourth Regional Groundnut Workshop for Southern Africa, 19–23 Mar 1990, Arusha, Tanzania. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Rweyemamu, C.L., and **Nyanda, M.K.** 1990. Evaluation of the effect of Minjingu rock phosphate (MRP) on groundnut yield and quality. Pages 155–159 *in* Proceedings of the Fourth Regional Groundnut Workshop for Southern Africa, 19–23 Mar 1990, Arusha, Tanzania. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Sandhu, R.S. 1985. Groundnut breeding program in Zambia. Pages 7–15 *in* Proceedings of the Regional Groundnut Breeders Group Tour, 25 Feb–1 Mar 1985, Zimbabwe, Zambia, Malawi. Lilongwe, Malawi: SADCC (Southern African Development Coordination Conference)/ICRISAT (International Crops Research Institute for the Semi-Arid Tropics) Groundnut Project. (Limited distribution.)

Sandhu, R.S., Kelly, G., and **Kannaiyan, J.** 1985. Groundnut production and research: problems and priorities in Zambia. Pages 107–113 *in* Proceedings of the Regional Groundnut Workshop for Southern Africa, 26–29 Mar 1984, Lilongwe, Malawi. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Sandhu, R.S., Mulila, J. M., and **Syamasonta, B.M.** 1989. SADCC regional groundnut variety trials – a review of progress made in Zambia during 1987/88. Presented at the Second SADCC Groundnut Breeders and Agronomists Meeting, 13–16 Mar 1989, Lilongwe, Malawi.

Shumba, E.M. 1983. Factors contributing to a decline in groundnut production in the Mangwende-Murewa district, and the need for a technical research input. Zimbabwe Agricultural Journal 80:251–254.

Sibale, P.K. 1985. Groundnut breeding in Malawi. Pages 27–31 *in* Proceedings of the Regional Groundnut Breeders Group Tour, 25 Feb–1 Mar 1985, Zimbabwe, Zambia, Malawi. Lilongwe, Malawi: SADCC (Southern African Development Coordination Conference)/ICRISAT (International Crops Research Institute for the Semi-Arid Tropics) Groundnut Project. (Limited distribution.)

Sibale, P.K., and **Kisyombe, C.T.** 1980. Groundnut production, utilization, research problems, and further research needs in Malawi. Pages 249–253 *in* Proceedings of the International Workshop on Groundnuts, 13–17 Oct 1980, ICRISAT Center, India. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Sibuga, K.P., Bwana, E.N., and **Mwakitwange, F.E.,** 1989. Effect of time of weeding on groundnut yield. Pages 213–217 *in* Proceedings of the Third Regional Groundnut Workshop for Southern Africa, 13–18 Mar 1988, Lilongwe, Malawi. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Sibuga, K.P., Songambele, S.S., and **Kakema, T.P.N.** 1990. Influence of sowing dates on growth and yield of groundnuts in Tanzania. Pages 183–188 *in* Proceedings of the Fourth Regional Groundnut Workshop for Southern Africa, 19–23 Mar 1990, Arusha, Tanzania. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Simons, J.H. 1985. Groundnut crop protection work in the Tanzania oilseeds research project. Pages 93–97 *in* Proceedings of the Regional Groundnut Workshop for Southern Africa, 26–29 Mar 1984, Lilongwe, Malawi. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Sithanantham, S., Sohati, P.H., Syamasonta, B., and **Kannaiyan, J.** 1990. Screening for resistance to sucking insects among groundnut genotypes in Zambia. Pages 117–120 *in* Proceedings of the Fourth Regional Groundnut Workshop for Southern Africa, 19–23 Mar 1990, Arusha, Tanzania. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Smartt, J. 1978. Makulu Red – a 'green revolution' groundnut variety? Euphytica 27:605–608.

Sohati, P.H., and **Sithanantham, S.** 1990. Relative damage and extent of yield losses due to insect pests on groundnut in Zambia. Pages 113–116 *in* Proceedings of the Fourth Regional Groundnut Workshop for Southern Africa, 19–23 Mar 1990, Arusha, Tanzania. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Subrahmanyam P. 1991. Diseases of groundnut in the SADCC region. Presented at the First Steering Committee Meeting, 16–17 Apr 1991. Lilongwe, Malawi: SADCC (Southern African Development Coordination Conference)/ICRISAT (International Crops Research Institute for the Semi-Arid Tropics) Groundnut Project. (Limited distribution.)

Subrahmanyam, P., Rao, V.R., McDonald, D., Moss, J.P., and **Gibbons, R.W.** 1989. Origins of resistances to rust and late leaf spot in peanut (*Arachis hypogaea*, Fabaceae). Economic Botany 43:444–455.

Syamasonta, M.B. 1990a. A review of 'pops' research in Zambia. Pages 17–21 *in* Proceedings of the Fourth Regional Groundnut Workshop for Southern Africa, 19–23 Mar 1990, Arusha, Tanzania. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Syamasonta, M.B. 1990b. Achievements of the Zambia groundnut improvement program. Pages 61–66 *in* Proceedings of the Fourth Regional Groundnut Workshop for Southern Africa, 19–23 Mar 1990, Arusha, Tanzania. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Tarimo, A.J.P., and **Karel, A.K.** 1987. Insect pests of groundnut (*Arachis hypogaea* L.) in Tanzania and their control. Pages 95–100 *in* Proceedings of the Second Regional Groundnut Workshop for Southern Africa, 10-14 Feb 1986, Harare, Zimbabwe. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Tarimo, A.J.P., and **Mkesele, M.K.A.** 1987. The effect of plant population and defoliation on the yield of groundnut (*Arachis hypogaea* L.). Pages 91–94 in Proceedings of the Second Regional Groundnut Workshop for Southern Africa, 10–14 Feb 1986, Harare, Zimbabwe. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Taylor, B.R. 1985. Groundnut agronomy research in southeast Tanzania. Pages 99–101 *in* Proceedings of the Regional Groundnut Workshop for Southern Africa, 26–29 Mar 1984, Lilongwe, Malawi. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Wightman, J.A. 1989. Contribution of insects to low yields in southern Africa. Pages 129–140 *in* Proceedings of the Third Regional Groundnut Workshop for Southern Africa, 13–18 Mar 1988, Lilongwe, Malawi. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Discussion

P.W. Amin: How do early varieties in West Africa respond if a dry spell occurs at flowering time? Is earliness governed by genetic factors?

R. Schilling: Earliness is governed by genetic factors but low temperature can prolong the cycle. These varieties are adapted to low rainfall and short rainy season areas. Their earliness enables them to 'escape' drought, but they have no physiological tolerance to drought, therefore a dry spell at the time of flowering may result in low yields.

M.S. Basu: How does methyl bromide fumigation and storage methods like refrigeration and vacuum packing affect seed viability? Are these technologies available to small farmers?

R. Schilling: There is no negative effect on seed viability if the seed is well dried at the time of fumigation and also if an optimum dose of fumigant and a correct duration of fumigation are maintained. Refrigeration of shelled seed material between 0 and 2°C preserves seed viability for 3–4 years, but there are many practical problems in this method. Viability under vacuum packing of shelled seed is about 1 year and we find this as a more reliable method than refrigeration. These techniques should be applied only by specialized teams with proper equipment, as in the National Seed Service of Senegal.

N.B. Essomba: You have chosen dry Savannah regions of West Africa, ignoring humid regions of the same area. I would like to know whether it was purposefully done or due to lack of information?

R. Schilling: We have deliberately chosen to work on regions of West Africa having <1400 mm of annual rainfall with a unimodal pattern. It does not mean that humid regions with high rainfall and bimodal pattern in certain cases are less important in West Africa or that they do not have problems. In fact, these regions should not be neglected. Some interesting results have been obtained in some of these regions while testing the material from dry Savannah regions.

F. Waliyar: What are the reasons for prolonged maturity of the cultivar 55-437 in Botswana? Did you examine ICG 4747 and ICG 7888 for resistance to early leaf spot in Malawi?

P. Subrahmanyam: The low night temperature in Botswana could be one of the reasons for prolonged duration of the cultivar 55-437 there. The two genotypes ICG 4747 and ICG 7888 were received from Zambia along with several others and the material is being tested during the 1991/92 crop season for their disease reaction at Chitedze, Malawi.

P.E. Olorunju: Some varieties in southern Africa mature in 130–140 days or even take up to 190 days. This duration range seems to be one of the major problems in the region. How ICRISAT is planning to overcome this problem?

Z.A. Chiteka: Some spanish varieties take up to 140 days to mature in Botswana and Lesotho. This is mainly due to low night temperatures that result in slow growth and eventually cause a delay in maturity.

G.L. Hildebrand: In a comparative study of some varieties of groundnut in Botswana, Lesotho, and Malawi, some spanish types that matured in 115–125 days in Malawi took more than 190 days in Lesotho. In these areas, where night temperatures are below the threshold levels for groundnut growth, we have no other alternative except advising the farmers to grow other oilseed crops like sunflower to meet the requirements of vegetable oil.

M.V. Potdar: What is the contribution of mounding and ridge and furrow seedbed in groundnut productivity over flat? What is the extent of these practices in the SADCC region?

Z.A. Chiteka: There is no advantage in yield under various types of seedbeds if optimum plant population is maintained. In most areas of the region, groundnut is sown on ridges where furrow irrigation is possible, and on flat where sprinkler irrigation is available. In countries like Malawi where drainage is a problem, groundnut is generally grown on mounds. The type of mechanical equipment used for harvesting in a particular area also influences the choice of seedbed.

C.P.S. Yadav: How serious is the white grub problem in the SADCC region? Are these pests endemic to any areas?
Z.A. Chiteka: In general, the degree of damage by a variety of insect pests is underestimated in the region. Although white grub damage was observed in Zimbabwe, Malawi, and other parts of the region, there is no detailed work to quantify the losses caused by white grubs alone.

J.B. Misra: Oleic acid is important from the stability angle while linoleic acid is important from the human nutrition point. What is the significance of having a high oleic/linoleic (O/L) acid ratio in groundnut pods in West Africa and the SADCC region?
G.L. Hildebrand: It is contradictory, but shelf life of processed products decreases with a greater proportion of unsaturated fatty acids in the oil. International buyers give high consideration to a high O/L ratio.

Status of Groundnut Research and Production in South Asia

P.S. Reddy[1], M.S. Basu[1], M.A. Khaleque[2], M.S. Hoque[2], Naazar Ali[3], Shah Nawaz Malik[3], Hla Than[4], Tin Soe[4], B. Regunathan[5], B. Mishra[6], T.G.K. Murthy[1], and S.N. Nigam[7]

Abstract

*South Asia, comprising Bangladesh, Bhutan, India, Myanmar, Nepal, Pakistan, and Sri Lanka, accounts for about 43.4% of the world groundnut (*Arachis hypogaea*) area (8.6 million ha) and 35.7% of production (8.1 million t). The period coinciding with the Southwest monsoon is the main growing season in the region although the crop is grown in more than one season in India, Myanmar, and Sri Lanka. The low average yields of groundnut in the region result from: raising the crop mostly under rainfed conditions on marginal and submarginal lands with low levels of inputs, use of varieties with long maturity periods, susceptibility of the crop to a plethora of insect pests and diseases, and nonavailability of efficient farm machinery and quality seed. All countries in the region made sustained efforts in the development of improved technology, including development of high-yielding varieties, improved agronomic practices, new and efficient strains of* Bradyrhizobium, *and efficient and economical plant protection schedules for the control of major insect pests and diseases. When tested in the farmers' fields, the technology indicated much unrealized yield potential. The future crop improvement research in the region aims to concentrate on the areas of crop duration, fresh seed dormancy, resistance/tolerance to major biotic stresses, seed quality and production, and design and development of efficient farm implements and machinery. To realize full impact of research on groundnut production in the region, it is important to ensure adequate support price and market to the crop. The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) has contributed substantially towards the development of improved cultivars as well as offering training facilities to accomplish better human resource development in the region.*

Résumé

***Bilan de la recherche et de la production arachidière en Asie du Sud:** L'Asie du Sud, comprenant le Bangladesh, le Bhutan, l'Inde, le Myanmar, le Népal, le Pakistan et le Sri Lanka, représente environ 43,4 % de la superficie mondiale consacrée à la culture de l'arachide (*Arachis hypogaea*),*

1. Director, Project Coordinator (Groundnut), and Scientist, National Research Centre for Groundnut (NRCG)/ICAR, Ivnagar Road, P.O. Timbawadi 362 015, Dist. Junagadh, Gujarat, India.
2. Project Director (Oilseeds) and Senior Scientific Officer, Oilseed Research Centre, Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur, Bangladesh.
3. Principal Scientific Officer (Oilseeds) and Scientific Officer, Barani Agricultural Research and Development (BARD), National Agricultural Research Center, P.O. NARC, Islamabad, Pakistan.
4. Head, Plant Pathology, and Head, Oilseed Crop, Central Agricultural Research Institute (CARI), Myanmar Agricultural Service, Yezin, Pyinmana, Myanmar.
5. Research Officer, Regional Agricultural Research Centre, Makandura, Gonawila, N.W.P., Sri Lanka
6. Assistant Agronomist, National Oilseeds Research Programme (NORP), Nawalpur, Sarlahi, Nepal.
7. Principal Groundnut Breeder, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh 502 324, India.

ICRISAT Conference Paper no. CP 803.

Reddy, P.S., Basu, M.S., Khaleque, M.A., Hoque, M.S., Naazar Ali, Shah Nawaz Malik, Hla Than, Tin Soe, Regunathan, B., Mishra, B., Murthy, T.G.K., and Nigam, S.N. 1992. Status of groundnut research and production in South Asia. Pages 133–147 *in* Groundnut – a global perspective: proceedings of an international workshop, 25–29 Nov 1991, ICRISAT Center, India (Nigam, S.N., ed.). Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

soit 8, 6 millions d'hectares et 35,7 % de la production (8,1 millions de tonnes). La période coïncidant avec la mousson du sud-ouest est la principale campagne de la région, bien qu'on cultive l'arachide pendant plus d'une saison en Inde, au Myanmar, et au Sri Lanka. La faiblesse du rendement de l'arachide dans cette région résulte des causes suivantes: la culture se fait surtout dans des conditions pluviales, dans des terres marginales ou sub-marginales avec de faibles niveaux d'intrants, l'usage de variétés à long cycle, la sensibilité de cette culture à une multitude d'insectes nuisibles et de maladies, et la non disponibilité du machinisme agricole efficace et de semences de qualité. Tous les pays de la région ont fait des efforts acharnés pour développer une technologie améliorée, y compris la mise au point de variété à haut rendement, l'emploi de pratiques agronomiques améliorées, de sources nouvelles et plus efficaces de Bradyrhizobium, *et la programmation efficace et économique de protection des plantes pour la lutte contre les principaux insectes ravageurs et les maladies. La technologie, lorsqu'elle a été essayée dans les champs paysans, indiquait un grand potentiel de rendement. Les recherches futures sur l'amélioration de la culture dans cette région visent à se concentrer sur la durée de la culture, et la dormance des semences fraîches, la résistance/tolérance aux principaux stress biotiques, la qualité et la production des semences, la conception et l'élaboration de matériel et de machinisme agricoles efficaces. Pour tirer meilleur parti de la recherche sur la production arachidière de cette région, il est important de fournir un prix de soutien et le marché pour cette récolte. L'Institut international de recherche sur les cultures des zones tropicales semi-arides (ICRISAT) a contribué largement à mettre au point des cultivars améliorés et en même temps à offrir des possibilités de formation pour assurer une meilleure mobilisation des ressources humaines dans la région.*

South Asia, comprising Bangladesh, Bhutan, India, Myanmar, Nepal, Pakistan, and Sri Lanka accounts for 43.4% of the area (8.6 million ha) and 35.7% of the production (8.1 million t) of groundnut (*Arachis hypogaea*) in the world (FAO 1990, pp. 157–158). However, the average productivity in the region (940 kg ha^{-1}) remains below the world average. India is the leading groundnut producer in the region.

The Present Situation

Groundnut is the major oilseed crop in India and accounts for 45% of the area and 55% of the production of total oilseeds in the country. In other countries of the region, it ranks either second or third among the annual oilseed crops grown.

In India, groundnut is grown in three seasons, i.e., rainy (85% area), postrainy (10% area), and summer (5% area). The rainy season groundnut, which is grown during the Southwest monsoon period (June-November) is spread over the entire country and is generally rainfed. The postrainy season groundnut is confined to South India and is raised mostly in rice (*Oryza sativa*) fallows during October-March. The summer crop is restricted to the central Indian states of Gujarat, Maharashtra, and Madhya Pradesh, and is grown from January to May. The postrainy and summer crops are irrigated. During the last decade, the groundnut area has increased gradually from 7.4 million ha in 1981 to 8.0 million ha in 1990. However, the production fluctuated violently primarily because of erratic distribution of rainfall. The yield and production pattern of groundnut for three decades in India (1960–1990) are depicted in Figure 1. Groundnut yields fluctuated from 550 to 1100 kg ha^{-1} and consequently the total production also varied from 4.3 million t to 9.6 million t. The rise and fall in the yield and production coincided with the percentage deviation from the mean annual rainfall (DES 1990).

In Myanmar, groundnut is the second most important oilseed crop next to sesame (*Sesamum indicum*). Its area ranges between 0.53 million and 0.65 million ha depending on the weather conditions. The crop is grown in the winter (47%) and monsoon (53%) seasons. The monsoon crop is normally cultivated on upland areas of the dry zone tract, whereas the winter crop is mainly confined to riverside areas of central Myanmar and rice fields of delta areas. The monsoon season yield (760 kg ha^{-1}) is much lower than that of the winter season (1190 kg ha^{-1}).

In Pakistan, groundnut is an important cash crop in *Barani* (dry) areas of upper Punjab and parts of Northwest Frontier Province (NWFP). In Sind, it is grown under irrigated conditions. About 85% of the total groundnut area in Pakistan lies in the province of Punjab, 10% in NWFP, and 5% in Sind. Since groundnut cultivation was started in 1949, there has

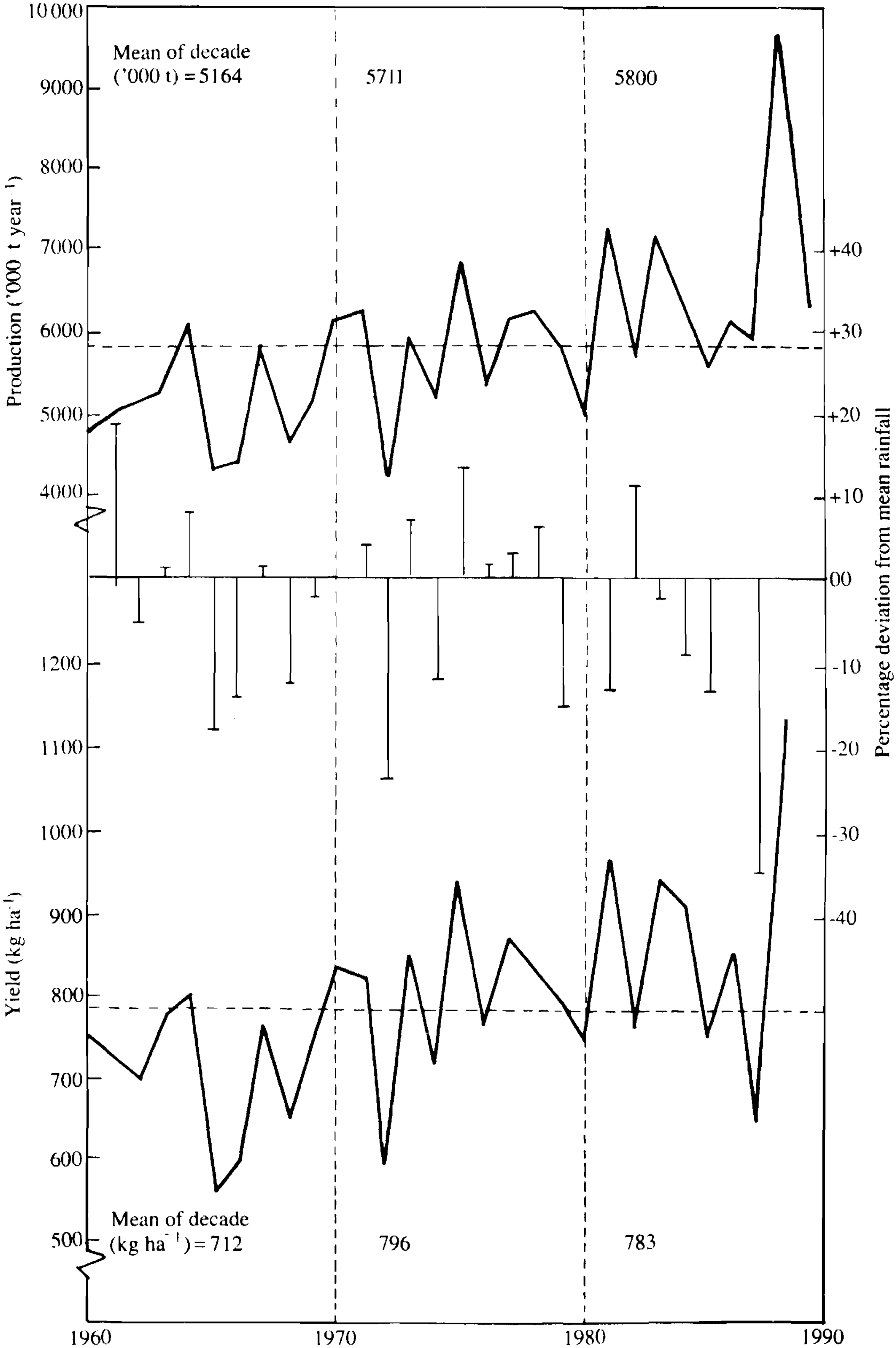


Figure 1. Yield and production pattern of groundnut in India. (Source: DES 1990.)

been a steady increase in area and production. During 1989/90, the total area under groundnut in Pakistan was 80 100 ha, with a production of 81 700 t of pods. The pod yield averaged 1019 kg ha^{-1}.

In Bangladesh, groundnut occupies the third largest area among the oilseed crops, next to rape seed/ mustard (*Brassica* sp) and sesame. Currently, groundnut is grown in an area of about 32 000 ha with a production of 43 000 t. The pod yield averages 1230 kg ha^{-1}. It is mostly grown in *Char* area (low lying inundated area in the rainy season) or river basins during the winter season (November to March) without irrigation. A small crop is grown in the rainy season on highlands mainly to provide seed for the winter crop.

In Sri Lanka, groundnut is mainly confined to the dry zone. It is also grown to a limited extent under coconut (*Cocos nucifera*) plantations in the intermediate zones, particularly in the Kurunegala district. The two main growing seasons in Sri Lanka are *Maha*, the period of major rains (mid-September to January), and *Yala*, the period of minor rains (mid-March to July). On an average, about 80% of the crop is grown in the *Maha* season. In 1989/90, the crop was grown in 10 990 ha, which produced 11 120 t pods with average productivity of 1015 kg ha^{-1}.

In Nepal, groundnut is a minor oilseed crop, grown in an area of about 5000 ha. Its cultivation is mainly confined to the Terai and inter-Terai areas and to a limited extent on mid-hill areas. In Bhutan, the crop is grown in small pockets mainly for local consumption.

Low Productivity and Causes

The average yield of groundnut in South Asia is low. In 1990 the pod yield obtained was 940 kg ha^{-1} as compared with 2387 kg ha^{-1} in the USA and a world average of 1141 kg ha^{-1} (FAO 1990, pp. 157-158).

The causes for low yields in the region are:

- Cultivation of the crop on marginal and submarginal lands under rainfed conditions subjected to frequent droughts,
- Poor agronomic practices and low levels of inputs because the crop is cultivated mainly by resource poor farmers,
- Use of low-yielding and late-maturing cultivars,
- Insect pests and diseases, and
- Inadequate availability of high quality seed of improved varieties.

In addition to these factors, poor marketing facilities and the lack of a support price also work against the farmers' interests in many countries. As groundnut is a labor-intensive crop, a lack of proper farm machinery for small holdings also retards the development of improved groundnut production systems in the region.

Research Accomplishments

Except for the large groundnut research program in India, the research input into the crop from other countries is relatively small. This is indicative of the place of groundnut in the overall agricultural economy of the countries. Recently under the aegis of the South Asian Association for Regional Cooperation (SAARC), a cooperative varietal testing program was initiated among member countries. Groundnut research in the region received a further stimulus with the establishment of the Asian Grain Legumes Network (AGLN) at ICRISAT.

Crop Improvement

Introduction and reselection with the exception of India continues to be the main method of crop improvement in the region. In the past decade, the importance of hybridization has been realized in India and now a majority of new breeding lines/cultivars are the result of hybridization between selected parents. However in countries where the research program is small and the scientists are entrusted with more than one crop, dependence on introduction of improved germplasm from various sources is heavy. ICRISAT has played an important role in introducing improved germplasm into the countries of the region.

Prior to 1980, breeding efforts were directed mainly towards improving yield potential. With the identification of resistance sources to major diseases and insect pests at ICRISAT and in national programs, resistance breeding received a strong stimulus resulting in the release of varieties with multiple resistances in India. Characteristics of registered/released varieties in the past decade in India (Basu and Reddy 1987) and other countries of the region are given in Table 1. A genetic gain of 1.3–3.2% annually has been achieved during the 1980s under rainfed cultivation in India (Nigam et al. 1991).

In spite of the release of so many varieties, the area covered with improved varieties in the region is

Table 1. Characteristics of released/registered groundnut varieties in South Asia.

Variety	Growth habit[1]	Year of release	Attributes
Bangladesh			
DA 1	SB	–	High shelling percentage (75%), no seed dormancy
DG 2	VB	–	Tolerant to late leaf spot and rust, seed dormancy for 40–50 days, 2-seeded bold pods
DM 1	VL	–	Dwarf plant, suitable for spring season, good for intercrop with sugarcane and maize, tolerant to late leaf spot and rust
Acc 12	VL	–	Tolerant to drought, late leaf spot, and rust, more than 50% pods 3-seeded
India			
KRG 1	SB	1981	Medium-sized 2-seeded pods, suitable for rainy and summer seasons
TG 17	SB	1982	Bold podded, pinkish testa, high harvest index, fresh seed dormancy up to 30 days
GG 2	SB	1983	Suitable for both rainy and postrainy summer seasons, dark green leaves, reticulated 2-seeded pod, drought tolerant
Co 2	SB	1983	Medium 2-seeded plump pods
Dh 8	SB	1984	Dark-green leaves, compact plant, tolerant to late leaf spot, 2-seeded small pods
TG3	SB	1985	Suitable for both rainy and summer seasons, tolerant to pod borer
ICGS 11	SB	1986	High-yielding, tolerant to bud necrosis disease and end-of-season drought, adapted to rainy and postrainy seasons
VRI 1	SB	1986	High shelling, fresh seed dormancy for a week, long pods with deep constriction and prominent beak
Girnar 1	SB	1988	Early-maturing, multiple resistance to foliar diseases, aflatoxin, jassids and drought
ICGS 44	SB	1988	High-yielding, tolerant to bud necrosis disease and mid-season drought
RG 141	SB	1989	Dark-green foliage
VRI 2	SB	1989	Pods bold with medium constriction, suitable for both rainfed and irrigated conditions
ICGS 1	SB	1990	High-yielding, suitable for both spring and rainy seasons, tolerant to bud necrosis disease
ICGS 37	SB	1990	High-yielding, tolerant to bud necrosis disease and end-of-season drought, suitable for summer cultivation
ICG(FDRS) 10	SB	1990	Resistant to rust and tolerant to late leaf spot and bud necrosis disease
VRI 3	SB	1990	Pods and seeds are small with slight to moderate constriction, suitable for delayed sowing in the rainy season
RSHY 1	SB	1991	Suitable for residual moisture conditions
M 197	VB	1982	Pods with less prominent venation and bold seeds
Chitra	VB	1984	Testa variegated on rose background
Kaushal	VB	1984	Compact plant, dark-green leaves, 1–3 seeded pods
UF 70-103	VB	1984	Suitable for summer season
MA 16	VB	1986	Bold seeded, suitable for confectionery trade
BG 3	VB	1988	Early-maturing
ICGS 76	VB	1989	High-yielding, tolerant to bud necrosis disease and mid-season drought, high shelling (73%) and good oil quality
ICGV 86590	SB	1991	High-yielding with multiple disease and insect pest resistance
GG 11	VR	1984	Bold podded
M 335	VR	1986	Bold podded with prominent reticulation, 2-seeded with light brown testa

Continued

Table 1. *Continued.*

Variety	Growth habit[1]	Year of release	Attributes
Myanmar			
SP 121	SB	–	2-1 seeded small pods, early-maturity
M 10	SB	–	2-seeded small pods, high shelling (76%), high oil (54%), early maturity
M 11	SB	–	2-1 seeded small-medium pods, high oil content (55%)
M 12	SB	–	2-3 seeded medium-sized pods, high oil content (55%)
M 15	SB	–	2-3 seeded medium pods, high shelling (77%), and high oil content (54%), seed dormancy for 2 weeks
Kyaung Gone	VB	–	2-seeded pods, seed dormancy up to 2 months
MS 2	VR	–	2-3 seeded pods, seed dormancy up to 3 months
Pakistan			
Banki	VB	–	Medium-sized 2-3 seeded pods with stable yields
BARD 699	SB	1989	High shelling (70%), high oil content, medium maturity, a composite of ICGS 37 and ICGS 44, suitable for areas with 500 mm rainfall
BARD 479	VB	–	Widely adapted, large-sized pods (under release)
No. 334	VR	–	Medium-sized pods with stable yield and wide adaptability
BARI 89	VR	–	Higher yield than No. 334, medium pod and seed size, suitable for areas with < 500 mm rainfall (under release)
Sri Lanka			
MI 1	SB	–	Medium-sized 2-seeded pods with pink testa
Red spanish	VL	1961	Large 3-seeded pods with dark pink testa
No. 45	SB	1982	High shelling (75%), 2-seeded pods with pink testa
South China	SB	–	Medium-bold pods with pink testa

1. SB = Spanish bunch, VB = Virginia bunch, VL = Valencia, and VR = Virginia runner

not large. Nonavailability of high quality seed of improved varieties at an affordable price remains the biggest bottleneck in increasing groundnut production in the region.

Agronomic Research

Seed rate and spacing

Maintenance of an optimum plant population is important to the success of groundnut cultivation. The seed rate depends on the growth habit and 100-seed mass of the variety and the recommended spacing. The most common spacing recommended for spanish and valencia cultivars in India is 30 × 10 cm. In the case of virginia bunch and virginia runner types, the most common spacing recommended is 30 × 15 cm. The common spacing adopted for spanish cultivar in Bangladesh is 40 × 15 cm. In Nepal, a spacing of 40 × 20 cm is common. In Myanmar, the recommended plant population for spanish and valencia types is about 260 000 plants, whereas for virginia bunch and runner it ranges from 150 000–190 000 plants ha^{-1}. In Pakistan, virginia runners are sown with a spacing of 60 × 10 cm. In the case of virginia bunch varieties, the recommended spacing is 45 × 10 cm. In Sri Lanka, a spacing of 24 × 15 cm for spanish bunch and 24 × 30 cm for virginia bunch is common.

Sowing time

For rainy season groundnut in India, the optimum sowing time ranges from the second fortnight of June to the first week of July, depending upon the receipt of adequate monsoon rains. Advance sowing by 10 days before the recommended sowing date by giving one presowing irrigation increases the yield considerably. In Pakistan, mid-April is the optimum sowing time in rainfed fallow areas and mid-March in irrigated areas. The last week of June to the third week of

July is optimum for sowing in Nepal. In Sri Lanka, the recommended sowing time for *Maha* season is mid-October to the end of October and April for *Yala* season.

Fertilization

The NPK fertilizer doses recommended for the major groundnut growing states in India are 15 kg N, 40–60 kg P_2O_5, and 0–45 kg K_2O ha^{-1}. All the P_2O_5 and K_2O and half of the N should be incorporated in the soil before sowing. Single superphosphate and ammonium sulphate are the preferred fertilizers for the groundnut crop. Application of gypsum is recommended in the sandy loam soils at 500 kg ha^{-1} in two equal split doses, at the time of sowing and peak flowering stage.

No fertilizer recommendations for groundnut are reported from Bangladesh. In Myanmar, application of phosphate and potash fertilizer as a single preplant dose at the rate of 30–60 kg ha^{-1}, depending on the fertility level of the land, and 9000 kg farmyard manure ha^{-1} at the time of land preparation is recommended. Gypsum is recommended at 150–200 kg ha^{-1} for low calcium soils in the deltaic regions. For Nepal, a fertilizer dose of 20–40–20 kg NPK ha^{-1} was found to be optimum. From multilocational trials in Pakistan 20 kg N and 80 kg P_2O_5 ha^{-1} were found appropriate to produce high pod yields. In the case of sandy soils or in areas intensively cropped with all crop residues removed, application of 50 kg K ha^{-1} is also suggested. In addition, 500 kg gypsum ha^{-1} is also recommended at the pegging stage (BARD 1989). Recommended fertilizer doses in Sri Lanka include 30 kg N, 65 kg P_2O_5, and 45 kg K_2O ha^{-1} as basal application and 30 kg urea ha^{-1} as top dressing at the flowering stage. In noncalcic Latosols and Regosols, 100 kg ha^{-1} gypsum application is also recommended to avoid 'pops' (empty pods) in the produce. However, on-station trials have also indicated a beneficial effect of organic manure and coir dust on groundnut production.

Micronutrients

Micronutrients play an important role in increasing the productivity of groundnut in India. The soils in the states of Andhra Pradesh, Tamil Nadu, and Punjab are deficient in zinc. Presowing application of zinc sulfate to the soil at 25 kg ha^{-1} once in 3 years, has been recommended. When zinc deficiency is noticed in the standing crop, foliar application of 0.2% zinc sulfate is recommended. Soils in the states of Tamil Nadu and Maharashtra are deficient in boron. This deficiency can be corrected either by addition of boron to the soil at 5–10 kg ha^{-1} along with NP fertilizers or foliar spraying of boron at a 0.1% concentration. In Maharashtra State, spraying of 0.1 ppm boric acid (300 mg of boric acid in 500 L of water) at 30 days after sowing (DAS) resulted in 10% and at 50 DAS resulted in 15% increased pod yield.

Iron chlorosis in groundnut has been reported from the calcareous black soils of high pH in the states of Tamil Nadu, Gujarat, Karnataka, and Maharashtra. Spraying of 1% ferrous sulfate plus 0.1% ammonium citrate corrects the deficiency to some extent. The spanish bunch varieties JL 24, Girnar 1, and GG 2 are found to be tolerant to iron chlorosis.

Weed control and earthing-up operations

Weeds cause maximum reduction in pod yield up to 45 DAS. Later on they hinder other field operations including harvesting. When the row sowing is done by seed drill, the crop is intercultured with bullock-drawn implements in India; the interculture operations reduce weeds and create a soil mulch.

Application of herbicides followed by one or two hoeings controls the weeds effectively. The recommended herbicides for groundnut in India are alachlor at 1.0-1.5 kg ai ha^{-1} or butachlor at 0.5 kg ai ha^{-1} as preemergence sprays within 2 days of sowing, or fluchloralin at 1.5 kg ai ha^{-1} in 500 L of water as preplant soil incorporation (PPI) sprays. PPI application of fluchloralin at 1 kg ai ha^{-1} resulted in a yield increase of 71% and a postemergence herbicide fluazifop-p-butyl at 0.25 kg ai ha^{-1} gave an increase of 50% over the unweeded check. In Nepal also, application of alachlor at 1.8 kg ai ha^{-1} controlled grassy and broad leaf weeds significantly. A study conducted at the National Agricultural Research Centre (NARC) in Pakistan during 1988 using fluazifop-p-butyl revealed that two applications at low rates (0.125 kg ai ha^{-1}) were more effective than one application at a high rate (0.5 kg ai ha^{-1}) in reducing weed infestation and increasing pod yields. In Sri Lanka, application of alachlor at rates ranging between 1.4 and 2.4 kg ai ha^{-1} at sowing, followed by hand weeding at the 6-week stage was effective in controlling weeds.

In Myanmar, experimental results on earthing-up of the crop indicated a yield loss of 14.82%. As a result, in 1982, nonearthing-up technology was transferred to 20 locations of monsoon groundnut. In Sri

Lanka, no yield increase was observed when earthing-up was done at flowering in the red-yellow Latosol soils.

Irrigation

Groundnut crop requires on an average 400–450 mm of water. In the Indian subcontinent, rainy season groundnut is subjected to many weather aberrations. Water stress at the critical growth stage (55–75 DAS) diminishes the yield drastically. If there is a failure of a single rain at the pod development stage, yield is reduced by about 50%. Provision of protective irrigation during the critical stages increased pod yield to the extent of 63% in Gujarat and 33% in Punjab.

Experiments conducted in India on postrainy and summer groundnut indicated that 11–12 irrigations are optimum for realizing high pod yield. More than 12 irrigations reduced pod yield. Withholding irrigations at 30–50 days and 90–105 days did not result in much loss of yield and quality, but the reduction was drastic at the 50–80 day stage. Although the best surface method of irrigation is 'border strip', farmers find 'check-basin' more convenient to use. Poor-quality irrigation water can limit production and quality of produce.

In Bangladesh groundnut is cultivated without irrigation in *Char* lands, where adequate moisture is available during the growing season. However, in highland areas one to two irrigations at the podding stage increase pod yields considerably. The *Maha* season crop in Sri Lanka is rainfed, whereas the *Yala* season crop receives full irrigation. Irrigation at 50% moisture depletion in reddish-brown soils gave optimum pod yield and water-use efficiency. However, in red-yellow Latosols irrigation at 25% depletion gave a 29% increase in pod yield over that at 50%.

Intercropping

In India, the most important cereal intercrops grown with groundnut are pearl millet (*Pennisetum glaucum*) and sorghum (*Sorghum bicolor*). Other crops intercropped with groundnut are black gram (*Vigna mungo*), castor (*Ricinus communis*), cotton (*Gossypium* sp), pigeonpea (*Cajanus cajan*), and sunflower (*Helianthus annuus*). The ratio of groundnut to intercrop varies from 1:1 to 1:8 depending on the location and intercrop species.

In Nepal, intercropping of groundnut with maize (*Zea mays*) is widely practiced. In Pakistan, groundnut is intercropped with maize, pearl millet, and sorghum in small pockets. In Bangladesh, intercropping of groundnut with sugarcane (*Saccharum officinarum*) and maize is recommended. In Sri Lanka, groundnut is normally grown as a sole crop.

Harvest, drying, and storage

The crop is mainly harvested manually. Plants are pulled out by hand at the time of maturity. Occasionally hoes and bullock-drawn diggers are also used to dig plants out. In the case of small holdings, the pods are stripped off the plants soon after harvest and carried home for drying. In the case of large holdings, plants are either left in windrows or in small heaps for sun drying before stripping off pods by mechanical threshers. Proper drying of groundnut produce is very important. The moisture content in pods should be brought down to around 8% before storage since higher moisture levels in the produce are congenial for the production of aflatoxin by yellow mold (*Aspergillus flavus*). The produce from the postrainy/summer crop in India loses viability quickly if dried under direct sunlight because of high temperatures prevailing at the time of harvest. To avoid this, the following procedure is recommended (Basu and Reddy 1989).

1. Tie the harvested plants into small bundles and keep them in a single layer with pods upward under shade. In the summer season, due to the natural movement of hot air, pods dry quickly.
2. When the bundles are dried, the pods may be detached from the plants and spread in a thin layer under shade for further drying. The following simple tests help to determine the correct stage for storage: the well-dried pods rattle upon shaking; when a seed is pressed between thumb and index finger it easily splits into two cotyledons; and when the surface of the seed is rubbed hard a portion of the testa comes off.
3. When the pods are thoroughly dried, as indicated by the above tests, they should be stored in polythene-lined gunny bags along with commercial grade calcium chloride at 300 g for each 40 kg bag. The calcium chloride should be placed in a wide-mouthed plastic bottle with pores in its upper portion. The bottle is covered with thin muslin cloth and kept at the central portion of the bag containing the pods.

The above procedure maintains viability up to 80% for a period of 10 months.

Experimental results in Bangladesh revealed that seeds with 9% moisture packed in polythene bags and stored in gunny bags retain their viability up to 90% for a period of 7 months.

Development of a viable storage technique for deltaic farmers is one of the future research thrusts in Myanmar.

Microbiological Research

The major groundnut crop in the region is grown without *Bradyrhizobium* inoculation. However, in the rice-based cropping system, the nodulation observed is generally poor. The waterlogged conditions in the rice fields reduce the population of native *Bradyrhizobium* to very low levels resulting in the low productivity of groundnut in the rice-based cropping system.

The National Research Centre for Groundnut (NRCG), Junagadh, India, has identified two effective strains of *Bradyrhizobium*, namely, IGR 6 and IGR 40, for higher productivity of groundnut in the postrainy/summer season (Joshi et al. 1989). In on-farm tests in West Bengal the increase in pod yield due to inoculation ranged from 14 to 16% with IGR 6 and 8 to 14% with IGR 40. Additionally, these strains are tolerant to Thiram and Bavistin, fungicides commonly used in seed treatment. These strains are commercially produced in India.

Bradyrhizobium inoculation gave 39–72% pod yield increase in on-farm trials in Myanmar. At 28 kg ha^{-1} of triple superphosphate (TSP), the inoculated plot yielded 2347 kg pods ha^{-1} while the control yielded only 1688 kg ha^{-1} and the plot applied with urea at 56 kg ha^{-1} produced 1816 kg ha^{-1}. The yield was further increased when the TSP dose was increased from 28 to 56 kg ha^{-1}. The *Bradyrhizobium* strains recommended for groundnut in Myanmar are TAL 1000 and TAL 1371. Commercial production of these strains is undertaken at the Agricultural Research Institute (ARI), Yezin, Myanmar.

At ICRISAT, a large number of *Bradyrhizobium* strains have been collected and tested for nitrogen-fixing ability in combination with a range of cultivars and germplasm lines. Field trials in many parts of India have shown that it is possible to increase yields of groundnuts by inoculation with *Bradyrhizobium*, even in fields where groundnuts have been grown for many years. ICRISAT has published an information bulletin on 'Nitrogen nutrition of groundnut in Alfisols'. This bulletin by Nambiar (1990) covers aspects of demand and acquisition of nitrogen by groundnut, results of experiments conducted in Alfisols at ICRISAT Center to improve groundnut productivity with *Bradyrhizobium* inoculation and fertilizer N, together with those relating to host-cultivar specificity, and possible problems in applying this information to farmers' fields. More attention will now be given to nitrogen nutrition in irrigated groundnuts, especially in the rice-based cropping systems of the region.

Plant Protection Research

A wide range of pests and diseases attack groundnut and cause considerable losses in yield in South Asia. Research efforts designed to tackle these biotic stresses in a more systematic manner are under way by national programs in collaboration with ICRISAT. In addition, several vertebrate pests such as rats, wild boars, crows, and squirrels can cause extensive damage to the crop when groundnut holdings are small.

Insect pests

The groundnut crop in the region is attacked by a number of insect pests from sowing to storage. In spite of advances in technology, losses by pests have been increasing in recent years, possibly due to changing cropping patterns and overlapping cultivation seasons. The major pests include leaf miner (*Aproaerema modicella*), white grub (*Lachnosterna consanguinea*), red hairy caterpillar (*Amsacta albistriga*), termites, defoliators such as tobacco cutworm or armyworm (*Spodoptera litura*), gram caterpillar (*Helicoverpa armigera*), leaf webber (*Anarsia ephippias*), and sucking pests such as aphids, jassids, and thrips.

The main emphasis in the past has been on chemical control. Integrated pest management is now receiving more attention. At ICRISAT, research aims to effectively combine cultural practices and host-plant resistance to develop integrated pest management systems. The effects of cultural practices on the incidence of important pests are being studied and particular attention is being given to intercropping. In the recent past, genotypes have been screened for resistance to thrips, jassids, leaf miner, *Spodoptera*, and aphids. Breeders are incorporating these resistances into high-yielding commercially-acceptable cultivars, and several lines with good resistance to thrips and jassids have out-yielded control cultivars.

Aphids, jassids, and thrips. Spraying monocrotophos 0.05% or dimethoate 0.05% at several testing centers in India not only gave significantly greater yields but also resulted in the highest cost benefit ratio (CBR). The CBR for these chemical treatments ranged from 1:6.33 to 1:19.68.

Leafminer. Economic threshold studies indicated that chemical control should be adopted only when the number of mines reaches 61–70 per 100 leaflets. Carbaryl 50 WP 0.2% spray was most economical for controlling this pest, since the CBR obtained in the All India Coordinated Research Project on Oilseeds (AICORPO) trials ranged from 1:6.52 to 1:9.56.

Red hairy caterpillars. The pupae may be handpicked and destroyed in the field after summer plowing. Immediately after rainfall, light traps may be set up to attract and destroy the moths. The egg masses and larvae, which can easily be detected, may be collected and destroyed. Before the caterpillars develop hairs on their bodies they can be controlled effectively by spraying monocrotophos 40 EC at 1 L ha^{-1}. A biological control measure through the spray of nuclear polyhedrosis virus (NPV) at Tamil Nadu Agricultural University, Coimbatore, India, was found to be effective and economical. The virus may be sprayed twice against early instar larvae at 250 larva equivalent ha^{-1}.

Tobacco cutworm, gram caterpillar, and leaf webber. These pests can be controlled by spraying 0.05% quinalphos at 400 ml ha^{-1} (CBR: 1:6:2). Other insecticides like carbaryl 0.2%, endosulphan 0.04%, and parathion 0.05% are also effective. In the case of tobacco cutworm, the larvae are nocturnal in habit; hence, the control measures should be applied during the night time.

Whitegrub. Whitegrub is a major problem for groundnut in the sandy loam soils of North India and Pakistan. Due to whitegrub infestations, the area under groundnut has declined considerably during the last two decades in the states of Uttar Pradesh, Rajasthan, and Punjab in India. The following integrated control measures can help to keep the pest under check:

- The field should be plowed twice during May–June to expose beetles present in the soil.
- Wherever possible, the crop should be sown early (between 10 and 20 June) to reduce the damage.
- The adult beetles should be killed by spraying the preferred host trees with carbaryl 50 WP or 50 ml Folithion®/Sumithion® 50 EC in 100 L of water.
- The soil may be drilled with phorate or carbofuran or sevidol granules at 25 kg ha^{-1} at least 1 week before sowing.
- Wherever the incidence is moderate, a cheap method of seed treatment may be adopted by treating the seed with chloropyriphos at 1.25 L (100 kg $seed)^{-1}$.

Diseases

The important groundnut diseases in the region are early and late leaf spots (*Cercospora arachidicola* and *Phaeoisariopsis personata*), rust (*Puccinia arachidis*), *Aspergillus flavus*, collar rot, dry-root rot, stem rot (*Sclerotium rolfsii*), and bud necrosis disease (BND).

Some of these diseases can be controlled by using proper fungicides.

Leaf spots and rust. Bavistin® 0.05% + Dithane® M-45 0.2%, sprayed at 2–3 weeks interval, two or three times starting from 4–5 weeks after sowing can effectively control these foliar diseases. In AICORPO trials, this combination of fungicides resulted in the best control of both diseases and gave a CBR ranging from 1:14.8–24.4.

Collar rot and dry root rot. Seed treatment with 5 g thiram or 3 g of Dithane® M-45 or 2 g Bavistin® (kg of $seeds)^{-1}$ can minimize the incidence of these diseases in the field.

Stem rot. The seeds should be treated as described for collar rot. In the soils infected with stem rot causing fungi, frequent disturbances of plant and soil should be avoided to prevent the stems from coming to contact with the organism. In such soils, herbicides may be used to minimize the disturbance of the soil due to manual weeding.

Breeding for resistance to diseases has received more attention in the region, particularly in India. Significant progress has been made in developing cultivars resistant to rust, late leaf spot, and bud necrosis diseases.

Rust and late leaf spot

At ICRISAT, several *A. hypogaea* genotypes and interspecific derivatives with high levels of resistance to rust and late leaf spot have been identified. These resistant sources are in extensive use in the disease resistance breeding programs of the region. Cultivars Girnar 1, ICG(FDRS) 10, and ICGV 86590 with resistance to rust and tolerance to late leaf spot have been released for cultivation in India.

Information bulletins on rust (Subrahmanyam and McDonald 1983) and leaf spots (McDonald et al. 1985) have been published by ICRISAT. These provide advice on their management and a good basis for further research on these diseases.

Bud necrosis disease

The bud necrosis disease is a virus disease transmitted by thrips. Chemical control of the vector is not always effective. Cultural methods such as timely sowing, closer spacing, intercropping with cereals, and use of vector-tolerant varieties (Kadiri 3, ICGS 11, ICGS 44, and others) help in reducing the disease incidence in the field.

Meanwhile, breeding efforts at ICRISAT are directed towards combining resistance to the vector and the virus in the high yielding background. Sources of resistance to thrips have been known for some time, but genotypes with tolerance to the virus have only been recently identified. The status of research on bud necrosis disease was recently summarized in an information bulletin published by ICRISAT (Reddy et al. 1990).

Aflatoxin contamination

The *Aspergillus* group of fungi invade groundnuts in the field and during postharvest handling. These fungi produce aflatoxins that are carcinogenic to humans.

Several genotypes with resistance to in vitro seed colonization by *A. flavus* have been known in the past. However, this form of resistance is effective only when the seed coat remains intact. Recently, genotypes that resist fungus invasion in the field and production of aflatoxin after fungus invasion have been identified. Breeding efforts are underway at ICRISAT and NRCG, Junagadh, India, to combine these forms of resistance with high pod yield. Proceedings of an international workshop on aflatoxin contamination of groundnut, held at ICRISAT Center in 1987, summarize the status of aflatoxin management research in the region and elsewhere (ICRISAT 1989).

Operational Research

In India, the production technology generated at different AICORPO groundnut centers was demonstrated in the rainy season in 1-acre farmer plots for 4 years (1980 to 1983). The results indicated considerable yield increases in the demonstration plots receiving the improved package instead of the farmers' procedure. The mean increase over the 4-year period ranged from 26.8% in Tamil Nadu to 100.8% in Rajasthan. A rough estimate showed that adoption of improved technology could increase the rainy season groundnut production from the present level of 5.3 million t to 7.5 million t – an increase of 40%.

In 141 on-farm trials conducted jointly by the Ministry of Agriculture, Government of India, and ICRISAT during 1987–1990, the improved groundnut varieties alone had an average pod yield advantage of 26% over local varieties, and the improved package of practices alone with local varieties had an advantage of 20% over the local recommended package of practices. Improved varieties, when used together with the improved package of practices, showed an average advantage of 60% over local varieties and local recommended practices.

In Pakistan, on-farm trials were organized during the past 5 years under the Barani Agricultural Research and Development (BARD) Project to transfer the improved production technology to the farmers in Rawalpindi Division. The improved technology included: timely sowing in straight rows, maintenance of optimum plant population by using 100 kg seed ha^{-1}, two weedings at 70 and 90 DAS, control of rats, harvesting the crop at 75% pod maturity, and use of improved machinery in field operations. Results from the demonstration plots were very encouraging, showing an average pod yield of 2450 kg ha^{-1} compared with 1400 kg ha^{-1} in the plots where local practices were used. Results further indicated that 50% yield can be increased only by rodent and weed control.

Technology Mission on Oilseeds in India

The Government of India instituted a Technology Mission on Oilseeds (TMO) in May 1986 with the objective of promoting production and processing of oilseeds for accelerating self-reliance in edible oils in the country. The Mission set a goal of producing 18 million t of oilseeds by 1989–90; it was achieved 1 year earlier in 1988–89. Groundnut production, which was at 6.21 million t during the premission period, increased to 7.81 million t after the TMO came into existence. It accounts for an increase in production of 25.7%.

Until 1986, the improved technologies developed for oilseed crops could not be adopted by the farmers for a multitude of reasons, namely: 1) unfavorable pricing policy and fluctuations in oilseeds prices in space and time to the disadvantage of the farmers, 2) limited developmental support for oilseeds, 3) non-availability of quality seed of high-yielding varieties in sufficient quantities at the right time, 4) low investment capacity of the bulk of the oilseed farmers, and 5) predominant cultivation of oilseeds under rainfed (86%) and input-starved conditions.

Since 1987–88, the scenario for oilseed production in the country became highly favorable to farmers due to the following integrated and mutually synergistic policies and measures initiated by the TMO: 1) declaration of minimum support prices to oilseeds with assured market support and an intervention mechanism, 2) availability of easy credit and other farmer support services, 3) progressive phasing out of imports of vegetable oils, and 4) building up of buffer stocks for effective market intervention to prevent steep falls or rises in price below and beyond specific price bands stipulated for major oilseeds.

All these measures had a cumulative and favorable effect on the open market price of oilseeds, which always remained much above the minimum support prices declared by the Government of India from time to time.

Machinery Development

Groundnut is a labor-intensive crop in the South Asia region, as most of the operations are carried out manually.

In India, machines available for shelling, threshing, and digging are popular with groundnut farmers. But for undertaking operations such as sowing, wet threshing, and gleaning (in sandy soils) suitable machinery has yet to be developed. Research work to develop this machinery is being undertaken at the Central Institute for Agricultural Engineering (CIAE), Bhopal, and also by the engineering departments of various state agricultural universities. The groundnut planter developed by Tamil Nadu Agricultural University, Coimbatore, is reported to be ideally suited for sowing groundnut in sandy loam soils.

In Pakistan, the BARD Project, in collaboration with the Farm Machinery Institute, has developed groundnut production equipment that is available from private manufacturers. The machines include a modified Italian mouthseed planter, a groundnut digger, and a power-operated thresher. In addition to sowing groundnut, maize, chickpea, soybean, and sunflower, the modified Italian planter can also do side band placement of fertilizers simultaneously. A tractor-mounted digger that can dig groundnut at the rate of 1–1.5 acres h^{-1} is rapidly gaining wide acceptance among groundnut growers. Similarly a thresher powered by a tractor with a crop intake capacity of 1200 kg h^{-1} is being manufactured commercially. A manually operated sheller imported from India with output of 40 kg seed h^{-1} with only 5% seed breakage is being considered for commercial production.

The Engineering Division of the Bangladesh Agricultural Research Institute (BARI), Bangladesh, has developed a hand-operated sheller for quick shelling of nuts. In Myanmar, development of a suitable groundnut planter is one important priority in future programs.

Marketing and Utilization

Marketing

Among the South Asian countries, a well-organized marketing system for groundnut exists only in India. In India, groundnut is marketed within the country either as pods or seeds, but the export is mainly in the form of seeds and groundnut cake. The marketing season for the rainy season groundnut generally commences in October and is over by February. The farmers either take their produce to the nearest assembling market or sell it at the farm gate. The markets concerned with groundnut trade fall under three categories: primary, secondary, and terminal (Patel 1988). Primary markets are mainly periodical, also known as weekly bazaars, which besides buying groundnut from farmers figure in the small retail sale. *Mandies* or *Gunj* are secondary markets that provide a permanent place for the daily transactions to take place with some amenities for the benefit of the sellers and buyers. The terminal markets are urban centers often connected by rail. Their stocks come from the primary and secondary markets.

The vegetable oil wing of the National Dairy Development Board (NDDB) was authorized by the

Government of India in 1988 to undertake the Market Intervention Operation (MIO) to ensure a fair price to the producer and a fair deal to the consumer. Prior to the MIO, the usual price spread was about 100% and in some years as much as 300% during the selling period despite huge imports of edible oil. The MIO brought about price stabilization in edible oils with a reasonable degree of success. The price spread was reduced to 25% in 1988/89, 50% in 1989/90, and 33% in 1990/91, despite the deficits not being met entirely through imports (NDDB 1991).

The vegetable oil and oilseeds project of NDDB has set up processing facilities throughout the country, with capacities of 3220 t day^{-1} for crushing, 1910 t day^{-1} for solvent extraction, and 710 t day^{-1} for refining oil. A storage capacity of 170 000 t for oilseeds and 86 550 t for oil has also been built. A National Oil Grid is being established with storage capacities at strategic locations, packaging stations spread all over the country, and an economical transport system to move oil and oilseeds from surplus to deficit zones.

Utilization

In India, about 81% of the groundnut produce goes for oil extraction, 12% as seed, 6% for edible use, and 1% for export. Handpicked and selected (HPS) groundnuts often referred to as "table nuts" and the deoiled cake are the main items of export.

In Myanmar, 70% of the groundnut produce is processed for oil, 20% as seed, and the remaining 10% for direct consumption as roasted, fried, or boiled groundnuts. In Bangladesh, Bhutan, Pakistan, and Sri Lanka, and Nepal, groundnut is used mainly for direct consumption.

Future Scope of Expansion of Groundnut Area in South Asia

In addition to increasing productivity, there is a great scope for increasing the area under groundnut cultivation in South Asia.

In Bangladesh, there is a scope to increase groundnut area without affecting other major crops mainly in coastal areas and river banks with silted soils, where no other crops except sweet potato (*Ipomoea batatas*) and water melon can be grown. Groundnut can be a good substitute for these crops on those lands.

In India there is only a limited scope for expanding the rainy season groundnut area as a sole crop in the highlands of Orissa, northern Bihar, and tribal belts of Andhra Pradesh and Madhya Pradesh. But there is enormous scope for groundnut as an intercrop with the traditional rainy season crops. Groundnut can be intercropped: with cotton and sorghum in the medium-black soils of Maharashtra, Karanataka, and Andhra Pradesh; with sugarcane in Maharashtra and Gujarat; with tobacco in Gujarat; and with coconut and cassava (*Manihot esculenta*) in Tamil Nadu and Kerala.

The area under postrainy irrigated summer groundnut has nearly doubled in India in the last decade, from 0.8 million ha in 1980–81 to 1.5 million ha in 1988–89. It may not be unrealistic to expect further expansion of the postrainy summer area to 2 million ha by the turn of the century. The high yield levels normally obtained from summer crops and high water-use efficiency are the major attractions to growing this crop in larger areas.

On the basis of soil type, climate, and irrigation facilities, it has been estimated that there is 1.4 million ha potential area where groundnut can be grown in Pakistan. Under the crop diversification program in Mahaweli Command Project area, potential exists for increasing the area under groundnut in Sri Lanka. Due to competition with maize and sugarcane (*Saccharum officinarum*), the groundnut area in the rainy season in Nepal is unlikely to increase. However, spring cultivation (Feb-Jun) in rice fallows with irrigation offers a possibility of expansion of the groundnut area in the country.

Future Thrusts in Groundnut Research

The important thrust areas for future research to overcome the production constraints in South Asia are as follows:

- Development of early-maturing varieties suitable for areas where the growing season is short, end of season droughts are frequent, and the crop is grown in rice-based systems with residual moisture;
- Incorporation of 2–3 week fresh seed dormancy in spanish varieties;
- Development of varieties resistant or tolerant to abiotic stresses such as drought in Bangladesh, India, Pakistan, and Myanmar, cold in India, shade for intercropping in coconut plantations in South India and Sri Lanka, and acid soils in northeastern India and Nepal;

- Development of varieties resistant or tolerant to major diseases such as late leaf spot and rust (all South Asian countries), bud necrosis disease (India, Pakistan, and Sri Lanka) and major insect pests, such as leaf miner in India and Nepal, and sucking pests in all South Asian countries;
- Development of varieties resistant to *Aspergillus flavus* and aflatoxin contamination in all South Asian countries;
- Research on methods of ensuring seed viability especially in summer season crop in Bangladesh, India, and Pakistan; and
- Design and development of suitable implements for farm operations such as shelling (Pakistan and Sri Lanka), sowing (India, Pakistan, and Sri Lanka), digging (India, Nepal, Pakistan, and Sri Lanka), and threshing (Pakistan and Sri Lanka).

In addition to the above research areas, the developmental activities in the region will involve creation of infrastructure for seed production and marketing.

ICRISAT's Contribution to Groundnut Improvement in South Asia

Development and Release of Improved Varieties

In India, the following varieties were released from the ICRISAT-bred material tested under the AICORPO trials: ICGS 11 (1986), ICGS 44 (1988), ICGS 76(1989), ICGS 37 (1990), ICGS 1 (1990), ICG (FDRS) 10 (1990), ICGS 5 (1990), and ICGV 86590 (1991). In addition to these, five more varieties selected from ICRISAT-supplied segregating material were released in India during 1984–89, namely, Spring Groundnut 84, ALR 1, VRI 1, Girnar 1, and RG 141. In Pakistan, two new varieties, namely, BARD 699 (released) and BARD 479 (under release), were selected from ICRISAT's material. Pakistan has also identified short-duration lines ICGS (E) 52 and ICGS (E) 56, which are being considered for release in dry areas. In Nepal, the early-maturing varieties of ICRISAT, namely, ICGS 30, ICG 789, and ICGS (E) 52, recorded 15 to 18% higher yield over the check variety B-4. In Myanmar, two varieties introduced by ICRISAT, ICG 7827 and ICG 799, were released as Sinpadetha 2 and 3 during 1984–85. In Sri Lanka, the following ICRISAT breeding lines produced high yields at different centers: confectionery types, ICGV 86552 and 86558, yielded over 3 t ha^{-1} at *Maha* Illuppallama; ICGV 88367 and 88379 recorded 4 t ha^{-1} at Araganwila; ICGV 87140 showed tolerance to leaf spots and rust and yielded 4 t ha^{-1} at Kilinochchi; and ICGV 87151 produced record yield of 7 t ha^{-1} and ICGV 86028 produced 6 t ha^{-1} under supplemental irrigation at Girandurukotte.

Training

ICRISAT provided training to the technicians and scientists in the areas of groundnut research and production. There was a periodical exchange of visits by the groundnut scientists of ICRISAT and those of the South Asian countries for discussions on production constraints and to facilitate information transfer.

Technology Transfer

The groundnut production technology generated at ICRISAT is being transferred to the farmers in India under the Legumes On-farm Testing and Nursery (LEGOFTEN). The National Dairy Development Board (NDDB) popularized ICRISAT's technology in an area of 10 000 acres in 1990–91. On-farm trials are in progress in Sri Lanka and Nepal under the Asian Grain Legumes On-farm Research Project.

Acknowledgment

The authors wish to thank Mr C. Rajgopal Reddy for reviewing the manuscript and making useful comments.

References

BARD (Barani Agricultural Research and Development Project). 1989. Annual report 1988–89. Islamabad, Pakistan: Pakistan Agricultural Research Council.

Basu, M.S., and **Reddy, P.S.** 1987. Groundnut varieties of India. Junagadh, Gujarat, India: National Research Centre for Groundnut. 15 pp.

Basu, M.S., and **Reddy, P.S.** 1989. Technology for increasing groundnut production. Junagadh, Gujarat, India: National Research Centre for Groundnut. 18 pp.

DES (Directorate of Economics and Statistics). 1990. Indian agriculture in brief. 23rd edn. Delhi, India: Controller of Publications. 460 pp.

FAO. 1990. 1989 Production Yearbook, vol. 43. Rome, Italy: FAO.

ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1989. Aflatoxin contamination of groundnut: proceedings of the International Workshop, 6–9 Oct 1987, ICRISAT Center, India. Patancheru, A.P. 502 324, India: ICRISAT.

Joshi, P.K., Kulkarni, J.H., and **Reddy, P.S.** 1989. IGR 6 and IGR 40, two effective *bradyrhizobium* strains for rabi/summer groundnut production. Junagadh, Gujarat, India: National Research Centre for Groundnut. 9 pp.

McDonald, D., Subrahmanyam, P., Gibbons, R.W., and **Smith, D.H.** 1985. Early and late leaf spots of groundnut. Information Bulletin no. 21. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Nambiar, P.T.C. 1990. Nitrogen nutrition of groundnut in Alfisols. Information Bulletin no. 30. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

NDDB (National Dairy Development Board). 1991. Twenty-fifth annual report 1990–91. Anand, Gujarat, India: NDDB. 48 pp.

Nigam, S.N., Dwivedi, S.L., and **Gibbons, R.W.** 1991. Groundnut breeding: constraints, achievements, and future possibilities. Plant Breeding Abstracts 61:1127–1136.

Patel, N.V. 1988. Distribution, area, production, and trade. Pages 12–23 *in* Groundnut (Reddy, P.S., ed.). New Delhi, India: Indian Council of Agricultural Research.

Reddy, D.V.R., Wightman, J.A., Beshear, R.J., Highland, B., Black, M., Sreenivasulu, P., Dwivedi, S.L., Demski, J.W., McDonald, D., Smith Jr, J.W., and **Smith, D.H.** 1990. Bud necrosis: a disease of groundnut caused by tomato spotted wilt virus. Information Bulletin no. 31. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Subrahmanyam, P., and **McDonald, D.** 1983. Rust disease of groundnut. Information Bulletin no. 13. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Groundnut Production and Research in Southeast Asia

S. Jogloy[1], R.M. Abilay[2], Tran Van Lai[3], S.Z. Ramawas[4], Khamsao[5], T. Adisarwanto[6], and A. Kasno[6]

Abstract

*Groundnut (*Arachis hypogaea*) is one of the major food legumes in Southeast Asia. It is grown by small farmers throughout the region. Yields are quite low (averaging 954 kg ha^{-1}) because of constraints from weeds, plant diseases, insect pests, and improper management. Groundnut has been sown in various cropping systems. Most groundnut produced is used for local consumption in various forms. Significant research progress has been made in the Philippines, Indonesia, Vietnam, Malaysia, and Thailand. Limited progress has also been made in Laos.*

Résumé

Production et recherche arachidières dans le Sud-Est asiatique: *L'arachide (*Arachis hypogaea*) est l'une des principales légumineuses alimentaires en Sud-Est asiatique. Elle est cultivée partout par de petits exploitants. Les rendements sont assez faibles (en moyenne 954 kg ha^{-1}) à cause des contraintes causées par des adventices, des maladies, des insectes ravageurs et de mauvaises gestions. Des systèmes de culture y sont variées. La majeure partie de la production sert à la consommation locale sous de diverses formes. Des progrès marqués de la recherche on été effectués aux Philippines, en Indonésie, au Vietnam, en Malaisie et en Thaïlande. Des progrès limités ont également été enregistrés au Laos.*

Groundnut (*Arachis hypogaea*) is the major food legume and oil crop of countries in Southeast Asia. It is grown by small farmers in all parts of this region, including the Philippines, Malaysia, Vietnam, Laos, Cambodia, Indonesia, and Thailand. It provides a significant source of cash income and is an important source of protein for rural people in the region. Groundnut production in Thailand, Vietnam, and Indonesia satisfies domestic needs, but production in the Philippines and Malaysia does not meet the demand for local consumption. The groundnut yields obtained are quite low in Southeast Asia due to various constraints on production. Efforts to produce improved cultivars combined with suitable crop management practices are needed to overcome constraints to groundnut production. This paper covers

1. Groundnut Breeder, Department of Agronomy, Faculty of Agriculture, Khon Kaen University, Khon Kaen 40002, Thailand.
2. Groundnut Breeder, Institute of Plant Breeding, College of Agriculture, University of the Philippines, Los Baños, College, Laguna 4031, Philippines.
3. Director, Grain Legume Research and Development Center, Vietnam Agricultural Science Institute, Hanoi, Vietnam.
4. Groundnut Breeder, Malaysian Agricultural Research and Development Institute (MARDI), Ketua Stesen, Stesen Penyelidikan Hortikultur, MARDI Station at Gajah Mati, 06400 Pokok Sena, Kedah Darulaman, Malaysia.
5. Deputy Director of Hat dok keo, Seed Multiplication Station, Department of Agriculture/Extension, Ministry of Agriculture and Forestry, Vientiane, Laos.
6. Agronomist and Breeder, Malang Research Institute for Food Crops, Malang, East Java, Indonesia.

This paper was made possible through support provided by the Office of Agriculture, Bureau of Research and Development, U.S. Agency for International Development under Grant No. DAN-G-00-0041-00.

Jogloy, S., Abilay, R.M., Tran Van Lai, Ramawas, S.Z., Khamsao, Adisarwanto, T., and **Kasno, A.** 1992. Groundnut production and research in Southeast Asia. Pages 149–156 *in* Groundnut – a global perspective: proceedings of an international workshop, 25–29 Nov 1991, ICRISAT Center, India (Nigam, S.N., ed.). Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

climatic and soil conditions for groundnut production, cropping systems, utilization, and progress achieved on groundnut production in Southeast Asia.

Climate and Soil of Southeast Asian Countries

The Southeast Asia region is located between latitudes 5°S and 21°N and between longitudes 90° and 130°E. The climate of this region is classified as tropical monsoon.

The Philippines

Groundnut can be grown during both wet (May-October) and dry (November-April) seasons. Optimum mean daily temperature ranges from 22° to 30°C. Daylength fluctuations in the Philippines do not seem to significantly affect the growth and yield of groundnut. Well-drained, medium-textured, slightly acidic (pH 5.5–6.5), and relatively fertile soils are suitable for groundnut production. Well-drained and medium-textured soils favor normal pod development and easy harvesting.

Malaysia

Malaysia has an equatorial climate. There is little variation in daylength. Temperature ranges from 22° to 30°C and annual rainfall is 2000–3000 mm. On the east coast, rainfall occurs from November-March due to the northeast monsoon and from May-September due to the southwest monsoon. Groundnut is grown between January and April (main season) and between May and September. In the west coast, groundnut is grown from April to July.

Vietnam

The climate is classified as monsoon. The rainy season is from November to April. The annual rainfall is 1100–2000 mm. Soils in the main groundnut production area are alluvial gray, sandy, and sandy loams. Many provinces have large areas of acid soil.

Laos

The climate is tropical monsoon with high rainfall (1500–2000 mm) and the average temperature is 30–35°C. The soil has low fertility with moderate acidity (pH 4.5–5.8); it is leached and has high erosion.

Indonesia

Indonesia is located along.the equator. It is marked by a tropical climate with wet and dry seasons. The rainfall for most of the country exceeds 2000 mm. Most of the soils are highly leached, acid, and poor. East and central Java are the major groundnut-producing regions. The majority of groundnut production is on dryland, totalling around 66%, and only 34% is on paddy fields. Groundnut is grown in rainy (Nov-Jan and Feb-May) and dry (Apr-Jun and Jul-Oct) seasons.

Thailand

The major groundnut growing regions are in northern and northeast Thailand and between latitudes 13° and 20° N. Loamy sand and sandy loams predominate with pH between 5.5 and 6.5. In general, soils in the production area have low water holding capacity, iow organic matter, low phosphorus, and are slightly acid (Vorasoot 1985). Groundnut is grown in two main seasons. In the rainy season (rainfall 1100–2300 mm) the crops are sown from May-August and July-October while in the dry season groundnut is grown from January-April.

Groundnut Production in Southeast Asia

Groundnut production in Southeast Asian countries is about 952 800 t on an area of 920 000 ha. The area under production has slightly declined in the Philippines, Malaysia, and Laos, while it has increased slightly in Vietnam, Indonesia, Cambodia, and Thailand during the years 1981–1990 (Tables 1 and 2). Yields obtained in Southeast Asian countries are quite low, compared with those reported from the USA and the People's Republic of China. Yields range from 0.8 t ha^{-1} in Laos to 1.2 t ha^{-1} in Thailand. Only from Malaysia were high yields reported (Table 3). They were based on fresh pod measurements. The main constraints on yield in Southeast Asia are presented in Table 4. They include abiotic factors such as drought, flooding, low soil fertility, and acidic soil. Low prices for produce and lack of finance to purchase inputs limit groundnut yield. Several biotic fac-

Table 1. Area under groundnut production ('000 ha) in Southeast Asia, 1981–1990.

Year	Countries						
	Thailand	Philippines	Malaysia	Vietnam	Laos	Cambodia	Indonesia
1981	122	55	5	120	11	10	508
1982	122	56	4	131	12	11	469
1983	125	55	3	141	12	8	478
1984	131	57	2	170	13	9	530
1985	125	50	2	213	7	10	497
1986	132	50	1	255	5	11	567
1987	122	55	2	238	6	11	551
1988	118	42	2	224	5	11	607
1989	-[1]	41	-	208	6	-	-
1990	-	-	-	204	8	-	-
Mean	124.6	51.2	2.6	187.4	8.5	10.1	532

1. Data not available.

Table 2. Groundnut production ('000 t) in Southeast Asia, 1981-1990.

Year	Countries						
	Thailand	Philippines	Malaysia	Vietnam	Laos	Cambodia	Indonesia
1981	147	50	21	160	9	14	425
1982	145	49	21	119	9	15	443
1983	147	36	17	126	10	6	457
1984	172	45	21	166	10	8	524
1985	171	45	21	202	5	10	499
1986	178	44	22	225	4	12	564
1987	162	47	20	232	6	10	533
1988	164	35	-[1]	214	5	12	587
1989	-	38	-	207	6	-	643
1990	-	-	-	202	8	-	-
Mean	160.8	43.2	20.4	185.3	7.2	10.9	525

1. Data not available.

Table 3. Average groundnut yields (kg ha^{-1}) in Southeast Asia, 1981-1990.

Year	Countries						
	Thailand	Philippines	Malaysia[1]	Vietnam	Laos	Cambodia	Indonesia
1981	1200	908	3500	900	766	1400	930
1982	1194	862	3500	900	747	1364	950
1983	1164	655	3400	900	797	800	960
1984	1375	789	3500	1000	769	889	990
1985	1312	900	3500	1000	780	1000	1000
1986	1350	879	3385	900	770	1000	990
1987	1369	853	3448	1000	880	909	970
1988	1388	833	3333	1000	830	1091	700
1989	-[2]	917	-	1000	970	-	1100
1990	-	-	-	1000	950	-	-
Mean	1288	844	3438	960	825	1056	954

1. Fresh pods.
2. Data not available.

Table 4. Constraints to groundnut production in Southeast Asia, 1981-1990.

Constraint	Countries					
	Thailand	Philippines	Malaysia	Vietnam	Laos	Indonesia
Drought	–	–	–	–		–
Flood			–			
Low soil fertility	–			–	–	–
Acidic soil		–				–
Low price of product	–	–	–	–		–
Insects						
Leaf miner	–		–			–
Leaf hopper	–	–				
Spidermites		–				
White grubs		–				
Aphids (*Aphis craccivora*)	–	–	–			
Helicoverpa	–		–			
Spodoptera litura	–		–	–	–	
Thrips	–		–			–
Dorylus orientalis	–					
Diseases						
Leaf spots	–	–	–	–	–	–
Rust	–	–	–			–
Bacterial wilt		–	–	–		–
Seedling blight	–		–			
Sclerotium wilt	–	–				–
Viruses		–	–			
Weeds	–	–	–	–	–	–
Drying	–	–	–		–	–
Shade		–				
Seed supply		–	–	–	–	–

tors such as insects, diseases, weeds, and shading also contribute to low yields.

Groundnut in Cropping Systems

The major groundnut production in Southeast Asian countries is in the upland areas as monocropping, and some groundnut is grown in paddy (*Oryza sativa*) fields. In the uplands of a few areas of Malaysia and Thailand, groundnut is intercropped with young rubber (*Hevea* spp) tree and oil palms (*Elacis* sp). In the Philippines groundnut is intercropped with corn (*Zea mays*) and coconut (*Cocos nucifera*).

Utilization

Most of the groundnut produced in Southeast Asian countries is consumed as fresh unshelled and shelled pods. The unshelled pods and seeds are processed for direct consumption as boiled, roasted, fried, or in confectioneries and in food ingredients. Groundnuts are also used for cooking oil and animal feed (as cake) throughout Southeast Asia, and for margarine in Malaysia and peanut butter in the Philippines.

Research Progress

Philippines

Breeding and cultivars released. Three new cultivars were released between 1986 and 1989, namely, UPL Pn6, UPL Pn8, and BPI Pn2. UPL Pn6 is resistant to late leaf spot (*Phaeoisariopsis personata*) and rust (*Puccinia arachidis*); it has a pink seed coat and medium size seeds. It is suitable for fried groundnut. UPL Pn8 is resistant to late leaf spot and rust, and moderately resistant to sclerotium wilt; it is long podded with 2-3 seeds, and is suitable for boiling. BPI Pn2 is moderately resistant to late leaf spot and rust; it has 2–3 seeds, a pink testa, and seeds bigger than UPL Pn6 or UPL Pn8.

Cultural practices. Gypsum should be applied before flowering to ensure bigger and plumper seeds. The seed size of UPL Pn4 and UPL Pn8 have been increased with the application of gypsum, and 'pops' incidence was minimized.

Usually, farmers do not apply fertilizer to groundnut because of the unpredictability of its response to fertilizers and to the crop's ability to use residual fertilizer from previous crops such as corn.

Irrigation during the dry season is done at sowing, flowering, pod initiation, pod filling, and before harvesting. A groundnut thresher is used during the wet cropping season. Stripping is done immediately after harvest, thus retaining pegs with the pods.

Weeds, diseases, and insect control. The most popular method of weed control in the Philippines is still manual weeding. Weeds should be controlled during the first 4–6 weeks after sowing to ensure good pegging and pod development.

Farmers do not usually spray pesticides to control pests and diseases of groundnut. However, they are encouraged to grow resistant cultivars.

The two problems in groundnut production in the wet season are severe infestation by white grubs (*Leucopholis irrorata*) and an extremely high incidence of peanut stripe.

***Rhizobium*.** From limited data there appears to be good potential for the utilization of biological nitrogen fixation in groundnut production (Paterno 1985). Further work is needed to define environmental conditions and management practices that would enhance the process. Also, there is a need to study the survival, competition, and persistence of rhizobia in monoculture crops and in groundnut intercropped with corn and coconut. Single fertilizers are not readily available in the country and farmers continue to use fertilizer mixtures.

Soils. Acidity problems occur in 1 100 000 ha in the country. A number of acid-tolerant genotypes have been identified (Samonte and Ocampo 1989) and these are now being evaluated further for aluminium tolerance. Some entries will soon be tested in selected acidic areas.

Malaysia

Breeding and cultivars released. Introduction and evaluation of cultivars and breeding lines are the cheapest and easiest way of identifying suitable cultivars for the Malaysian environments. Advanced breeding lines are imported and evaluated for adaptability, yield performance, quality, disease resistance, and shade tolerance. Superior genotypes will be released as commercial cultivars or be used as parents in breeding programs. A number of genotypes have already reached the advanced stages of release as cultivars.

In the hybridization program, established locally adapted cultivars are crossed to develop groundnut genotypes resistant to predominant diseases and for certain quality traits. Through this program, variety MKT 1 was released recently (Ramli and Zainab 1990).

Cultural practices. Most of the agronomic studies were concentrated on the management of the virginia types of groundnut. Optimum harvesting time for local processing is identified for each released cultivar. Studies on supplementary irrigation, seed filling, seed dormancy, and viability are done on cultivars recommended for commercial release.

Weeds, diseases, and insect control. The development of a practical screening technique is necessary for a breeding program to develop disease-resistant cultivars. The study on viable screening procedures is ongoing. Imported and locally selected lines are screened against predominant diseases, especially bacterial wilt (*Pseudomonas solanacearum*).

Laos

Research work on groundnut is very limited in Laos. Forty varieties were introduced from abroad and four varieties were collected locally. A varietal trial was conducted in order to identify promising lines for farmers. Trials were conducted to identify optimum sowing time and spacing. Because yields obtained from each trial were quite low, definite conclusions cannot be drawn. Presently, constraints to groundnut production still remain.

Table 5. Crop production practices followed in three regions of Vietnam.

Practice	Region		
	Ha Bac	Nghe Tinh	Long An
Land preparation			
Plow (no. of times)	1–3	2–3	1–2
Harrow (no. of times)	2–4	2–4	2–3
Spacing (cm)	20–30 x 10–15	25–30 x 10–15	15–20 x 15–20
Seed hill^{-1}	1–2	1	2–3
Seed treatment	none	hot water	none
Hilling up	yes	yes	none
Weeding (no. of times)	2	2–3	2–3
Irrigation (no. of times)	none	none	4–9
Fertilizers N:P:K (kg ha^{-1})	54:60:67	50:75:0	75:120:100
Lime (t ha^{-1})	0–0.4	0–0.3	0–1.0
Harvesting	by hand	by hand	by hand

Vietnam

Breeding. Breeding objectives are to release high-yielding, early-maturing cultivars for cropping systems. Sen Lai, a high-yielding cultivar, was released to farmers and six promising cultivars are under evaluation. Four early-maturing cultivars with high yield were identified, namely, ICGV 86055, ICGV 86015, ICGV 86048, and ICGV 86105.

Agronomic practices and crop management. Agronomic practices followed in three distinct production regions are shown in Table 5.

Pest and disease control. Bordeaux mixture and $CuSO_4$ are recommended for control of rust and leaf spot. Wofatox® 1Y and 0.15% metaphos are used for control of leaf-damaging insects.

Enhancing biological nitrogen fixation. Three promising *Rhizobium* strains, TAK 236, D 384, and TAL 110, with high nitrogen fixation ability have been isolated (Bich Loc et al. 1990). On an average, *Rhizobium* inoculation increased yields by 16%.

Application of phosphorus and lime. In acid soils where P and Ca are deficient, the application of phosphorus and lime are necessary for optimum growth and increased yield. Optimum quantities of P and Ca are 60–80 kg ha^{-1} of P_2O_5 and 500 kg ha^{-1} of $CaSO_4$.

Indonesia

Breeding and cultivars released. Groundnut breeding in Indonesia is designed to produce cultivars with high yields, early maturity, good seed quality, and resistance to major diseases such as bacterial wilt, rust, and late leaf spot. Introduction, hybridization, and selection were conducted. Several cultivars performed better than controls in yield trials. The recommended controls in Indonesia are Tupai, Kelinci, Tapir, and Gajah (Sumarno 1987). Four cultivars, Mahesa, Badak, Biawar, and Komodo, were released in 1991 (CRIFC 1991).

Cultural practices. Land preparation is carried out on drylands and wetlands. Groundnut is manually sown by using a dibbling stick, hand hoe, or animal-drawn plow. The seeding rate varies depending on the method of sowing. Hand sowing requires 50–90 kg ha^{-1} of seed with plant spacings of 30 × 15 cm or 30 × 20 cm. After sowing, only a few farmers apply fertilizer. However, the recommended fertilizer rate is similar at all places, consisting of 25–50 kg N, 30–50 kg P_2O_5, and 20–50 kg K_2O ha^{-1}; lime is recommended when groundnut is sown in acidic soil. Groundnut produced on wetland (during the dry season) should be irrigated 3–4 times, while that produced on dryland depends on rainfall alone.

Weeds, diseases, and insect management. Weeds are a major constraint to groundnut production. They reduce yields by as much as 45%. Hand weeding is commonly practiced by farmers. Herbicides are rarely used to control weeds.

Diseases such as leaf spots, rust, bacterial wilt, and peanut stripe virus contribute to reductions in yield. Research indicates that pod yield could be increased by more than 50% when rust and leaf spots were controlled.

Insect pests incidence in groundnut is less when compared with other grain legumes but occasionally leaf roller and leaf feeders are found attacking the crop. Farmers rarely have to use insecticides on groundnut. However, the actual losses from pest attacks are not known.

Harvesting and drying procedures. Harvesting is done by hand normally 85–95 days after sowing, because farmers usually grow early-maturing varieties. They thresh the pods by hand and then dry them for 6 to 7 days. At harvest the moisture content of the pods is high (40–50%). Pods are sun dried. Sorting of rotten pods, and small and shriveled seed is done after drying. Groundnut seed is stored in the shell for sowing, as well as for consumption.

Thailand

Breeding and cultivars released. Groundnut breeding work in Thailand is designed to produce cultivars with high yield, early maturity, drought tolerance, bold seeds, resistance to rust, leaf spots, and *Aspergillus flavus*, and suitable for boiling. Apart from suitability for cultivation in the main rainy season and in the dry season with irrigation, emphasis was also placed on developing cultivars suitable for before-rice and after-rice rainfed growing conditions (Patanothai et al. 1987). At present, six groundnut cultivars have been released. Two of them are spanish types with medium seed size, namely, Tainan 9 and Khon Kaen 60–1. Three cultivars have been released as boiling-type groundnuts, S.K. 38, Lampang, and Khon Kaen 60–2. They are valencia types with long pods with 3–4 seeds per pod and excellent pod appearance. One cultivar, Khon Kaen 60–3, was released as a large-seeded virginia-type groundnut. The seed size of Khon Kaen 60–3 is about twice as big as the other released cultivars. Several promising breeding lines from various breeding programs are being evaluated. We collaborate with North Carolina State University, USA, and ICRISAT.

Cultural practices. Several cultural practices have been studied in order to remove constraints and improve crop management.

Three recommended sowing times are early rainy season (mid April-May), late rainy season (July) and dry season (December-January). Land should be tilled 2–3 times up to 10–20 cm depth. Either whole pods or seeds are used for sowing. Sowing with different seed sizes does not affect germination, growth, or groundnut yields. Plant spacing of 30–60 cm × 10–20 cm is recommended depending on time of sowing, location, and cultivar. Weeds can cause yield reductions up to 30–70%, so two hand weedings at 15 and 30 days after sowing are recommended. Application of alachlor (3–4 L ai ha^{-1}) is recommended for pre-emergence treatment. Fertilizer (18 kg of N, 56 kg of P_2O_5, and 37 kg of K_2O ha^{-1}) is applied prior to sowing. Hilling up is done at 10 days after flowering. Gypsum as a source of Ca and carbofuran for control of subterranean ants (*Dorylus orientalis*) are also applied just before hilling up. Other forms of pest control are also utilized. Pod drying is also recommended as postharvest handling to reduce mycotoxin contamination. Small machinery has been developed for digging, stripping, and shelling.

Diseases. Combined losses from foliar diseases vary from 20–50% depending on seasons and locations. From rust alone the loss is about 10%, while leaf spots reduced pod yields by 13–15%. Loss from peanut stripe virus, averaged across all strains, is about 40%. Seedling blight (*Aspergillus niger*) could reduce stands by 15–50% (Wongkaew et al. 1987). Infector rows and detached leaf techniques have been used to evaluate groundnut genotypes for resistance to rust and leaf spots. Several lines were identified as resistant sources. Chlorothalonil or benomyl mixed with mancozeb is recommended for control of rust and leaf spot, while carboxin and thiram are recommended for treating seeds to control seedling blight. Peanut stripe virus can be controlled using virus-free seed. Screening varieties for resistance to *A. flavus* was conducted by using dry seed inoculation, but varieties resistant to *A. flavus* with acceptable agronomic characters have not been found.

Insects. Predominant insect pests of groundnut in Thailand are leaf miner (*Biloba subsecivella*), leaf hopper (*Jacobiasca formosana*), thrips (several species), aphids, *Helicoverpa*, and subterranean ants. Yield loss due to leaf miner is 50% and to subterranean ant, 32%. Monocrotophos is recommended for controlling leaf miner. Subterranean ants can be controlled by coconut meat baits. Baits were replaced weekly and ants trapped in the baits were destroyed. Insecticides recommended for control of leaf miner are also good for control of leaf hopper, thrips, aphids, and leaf defoliators. Groundnut genotypes were screened for resistance to leaf miner and leaf hopper. Several lines were identified as resistant.

Rhizobium. *Rhizobium* cowpea type and rhizobia such as *Rhizobium japonicum*, *R. lupini*, *R. trifolii*, and *R. meliloti* can form nodules in groundnut. Populations of *Rhizobium* in soil have been estimated. Little *Rhizobium* was found in soils not sown with legumes, while 10^6 cells g $soil^{-1}$ was found in soils sown with legumes. Results of several experiments indicated that no economic yield response to *Rhizobium* inoculation was found. By using N-15 technique, *Rhizobium* inoculation on groundnut was found to fix nitrogen at about 70 kg ha^{-1}; without *Rhizobium* inoculation native strain can fix nitrogen up to 57 kg ha^{-1}. *Rhizobium* strains THA 205, NC 92, Tel 1000, 32 H1, and T1 were found to fix nitrogen efficiently.

References

Bich Loc, N.T., Dan, N.T., and **Duong, N.** 1990. Strains studies on biological N-fixation of leguminous plant in Vietnam. Leguminous Plant Tropical Information 1:8-12.

CRIFC (Central Research Institute for Food Crops). 1991. High yielding varieties of food crops. Bogor, Indonesia: CRIFC.

Patanothai, A., Toomsan, S., and Waranyuwat, A. 1987. Progress of peanut breeding work in Thailand. Pages 8–20 *in* Proceedings of Peanut CRSP workshop, 19-21 Aug 1986, Khon Kaen, Thailand (Stalker, H.T., Waranyuwat, A., and Shew, B.B., eds.). Washington, D.C., USA: United States Agency for International Development.

Paterno, E.S. 1985. Utilization of microbial associations in peanut production – *Rhizobium*. Pages 43-54 *in* Peanut: proceedings of the First National Peanut Consultation and Peanut CRSP Review, 7-8 Feb 1985, Los Baños, Philippines. Book Series no. 39/1985. Los Baños, Laguna, Philippines: Philippine Council for Agriculture and Resources Research and Development.

Ramli, M.N., and **Zainab, R.S.** 1990. A new improved groundnut selection-line 7920B-3B. Presented at the Scientific Council Meeting, 28 Aug 1990, Malaysian Agricultural Research and Development Institute, Serdang, Malaysia.

Samonte, H.P., and **Ocampo, A.M.** 1989. Tolerance of mung bean, peanut, soybean and corn to acid soil conditions in the Philippines. The Philippine Agriculturist 72:137-146.

Sumarno. 1987. Legume varietal selection for conditions after lowland rice and for acid soils. Progress report. Bogor, Indonesia: Bogor Research Institute for Food Crops, and Central Research Institute for Food Crops.

Vorasoot, N. 1985. Agroclimatology in northeast Thailand. Proceeding of Soil, Water and Crop Management Systems for Rainfed Agriculture in Northeast Thailand, 25 Feb–1 Mar 1985, Khon Kaen, Thailand. Khon Kaen, Thailand: Khon Kaen University.

Wongkaew, S., Surin, P., and **Sommartaya, T.** 1987. Peanut pathology 1985 progress report from Thailand. Pages 24–28 *in* Proceedings of Peanut CRSP workshop, 19-21 Aug 1986, Khon Kaen, Thailand (Stalker, H.T., Waranyuwat, A., and Shew, B.B., eds.). Washington, D.C., USA: United States Agency for International Development.

Groundnut Production and Research in East Asia in the 1980s

Xu Zeyong[1]

Abstract

*East Asia is one of the major groundnut (*Arachis hypogaea*) growing regions in the world. In the late 1980s groundnut production was 6 000 000 t in the People's Republic of China, 43 000 t in Japan, and 26 000 t in South Korea. Groundnut production increased rapidly in the People's Republic of China in the 1980s. In the period 1970–1989 the average increase in area under groundnut was 50.5%, while production increased by 124.3% and yield increased by 48.3%. Major factors attributed to the increase of groundnut production include agricultural reforms started in the late 1970s, development of a market economy, increase of inputs into groundnut production, and application of improved varieties and changes in scientific techniques. Improved varieties now cover 95% of the People's Republic of China's total groundnut land. Major changes in scientific techniques that were applied included change of cropping system and development of summer groundnut in the northern region, application of plastic film mulch cultivation, application of narrow bed cultivation, increase of plant density, rational use of fertilizers, and effective control of diseases and insect pests.*

Résumé

Production et recherche arachidières en Asie orientale au cours des années 1980: *L'Asie orientale est une des principales régions mondiales de production arachidière (*Arachis hypogaea*). Au cours des dernières années 1980, la production d'arachide était de 6 000 000 t en Chine, 43 000 t au Japon et 26 000 t en Corée du Sud. La production arachidière a augmenté rapidement en Chine au cours des années 1980. Pendant la période 1970–1989, l'augmentation moyenne de superficie plantée d'arachide a été de 50,5%, tandis que la production a augmenté de 124,3%, et le rendement de 48,3%. Les principaux facteurs auxquels on attribue l'augmentation de la production arachidière comprennent les réformes agricoles inaugurées au cours des années 1970, le développement d'une économie de marché, l'augmentation des intrants de la production arachidière et l'usage de variétés améliorées ainsi que des changements des techniques scientifiques. Les variétés améliorées ont couvert 95% des superficies totales consacrées à l'arachide en Chine. Les principaux changements des techniques scientifiques appliquées comprennent des modifications du système de production et le développement d'arachide d'été dans la région nord, la disposition de bandes de plastique comme paillis, le recours à la culture sur plates-bandes étroites, l'augmentation de la densité du peuplement, l'usage rationnel d'engrais, et la maîtrise efficace des maladies et des insectes ravageurs.*

East Asia, including the People's Republic of China, Japan, and Korea, is one of the major groundnut (*Arachis hypogaea*) growing regions in the world. In the 1980s annual groundnut production in Japan and South Korea was about 50 000 t (on approximately 27 000 ha) and 23 000 t (on approximately 12 000 ha) (Tables 1 and 2). Japan imported an average of 35 000 t and South Korea 3050 t of shelled groundnut each

1. Plant Pathologist, Department of Plant Protection, Oil Crops Research Institute, Chinese Academy of Agricultural Sciences, Wuhan 430 062, Hubei, People's Republic of China.

Xu Zeyong. 1992. Groundnut production and research in East Asia in the 1980s. Pages 157–165 *in* Groundnut – a global perspective: proceedings of an international workshop, 25–29 Nov 1991, ICRISAT Center, India (Nigam, S.N., ed.). Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Table 1. Area, production, and yield of groundnut (in-shell) in East Asia in the 1980s.

	1979–1981			1985–1989		
Countries	Area ('000 ha)	Production ('000 t)	Yield (kg ha^{-1})	Area ('000 ha)	Production ('000 t)	Yield (kg ha^{-1})
The People's Republic of China	2346	3501	1487	3112	5954	1920
Japan	33	61	1854	24	43	1776
South Korea	12	19	1561	15	26	1766

Source: FAO Agricultural Production Yearbooks.

Table 2. Area, yield and production of groundnut (in-shell) in Japan, and South Korea (1984–89).

	Japan			South Korea		
Year	Area ('000 ha)	Yield (kg ha^{-1})	Production ('000 t)	Area ('000 ha)	Yield (kg ha^{-1})	Production ('000 t)
1984	29	1787	51	10	1696	17
1985	27	1884	51	12	2002	23
1986	24	1918	47	13	2113	28
1987	23	2031	46	22	1473	32
1988	22	1536	32	16	1746	29
1989	20	1500	30	15	1567	24

Source: FAO Agricultural Production Yearbooks.

year from 1984 to 1989. Since little information is available concerning groundnut production in Japan and South Korea, this paper deals mainly with groundnut production and research in the People's Republic of China in the 1980s.

Groundnut is one of the major oil crops in the People's Republic of China. Traditionally groundnut is used for cooking oil. However it has been increasingly used for food processing and export in recent years. Groundnut production has rapidly developed in the People's Republic of China in the 1980s. During this period the area under groundnut production increased from 2.95 to 3.3 million ha, and yields increased from 1800 to 2000 kg ha^{-1}. The People's Republic of China has become one of the largest groundnut producers in the world, with an output of 6 000 000 t.

Groundnut Production and Trade in the 1980s

Generally speaking, the development of groundnut production in the People's Republic of China can be divided into two phases in the 1980s. In the first phase from 1980 to 1984 the area under groundnut averaged 2 370 000 ha, the yield 1697 kg ha^{-1}, and production 4 020 000 t, representing increases of 30.1% in area, 39.2% in yield, and 80.7% in production compared with the 1970s. In the second phase from 1985 to 1989 the average groundnut area, yield and production each year were 3 100 000 ha, 1920 kg ha^{-1}, and 5 950 000 t, increases of 31.4%, 13.1%, and 48.2%, compared with those in the first 5 years. Groundnut area, yield, and production for periods from 1980 to 1989 are shown in Table 1. This represents an increase averaging 50.5% in area, 48.2% in yield, and 124.3% in production, compared with the 1970s (Tables 3 and 4).

Groundnut is distributed throughout the country. However it is mainly grown in three major regions, that is, the northern, central, and southern regions, which account for 95% of groundnut production. The northern region comprising Shandong, Henan, Hebei, Liaoning, Jiangsu, and Anhui Provinces is the most important one in the People's Republic of China. Production areas developed fastest there in the 1980s, increasing from 50% in 1970s to 60% of nation's total

Table 3. Area, production, and yield of groundnut pods in the People's Republic of China (1980–89).

Year	Area ('000 ha)	Production ('000 t)	Yield (kg ha^{-1})
1980	2339	3596	1537.5
1981	2472	3819	1545.0
1982	2416	3912	1623.0
1983	2201	3950	1792.5
1984	2415	4816	1987.5
1985	3318	6664	2010.0
1986	3299	5882	1815.0
1987	3022	6170	2040.0
1988	2977	5693	1920.0
1989	2946	5362	1815.0
Average	2740	4986	1808.8

Source: China Agriculture Yearbooks.

groundnut area in the 1980s. The southern region includes Guangdong, Guangxi, Fujian, and Taiwan Provinces, and accounts for 21.1% of the nation's total groundnut area. The third, the central region, includes Sichuan, Hubei, Hunan, Jiangxi, and Zhejiang Provinces, and accounts for 12% of the total national groundnut area.

In the late 1980s nine provinces, Shandong, Henan, Hebei, Liaoning, Anhui, Jiangsu, Guangdong, Guangxi, and Sichuan, all had production areas in excess of 100 000 ha. The area under groundnut in the four provinces, Hubei, Hunan, Fujian, and Jiangxi, was between 50 000 ha and 100 000 ha. Shandong Province is the largest groundnut producer in the country. The average groundnut sowing area and production each year from 1986 to 1990 was 760 000 ha and 1 980 000 t and accounted for 23.3% of the total national area and 32% of total national production of groundnut. The average yield from 1986 to 1990 in Shandong was 2602.5 kg ha^{-1}, one of the highest in the People's Republic of China (Guo Zhongguang 1991).

Export of groundnut had also developed rapidly in the People's Republic of China in the 1980s. Shelled groundnut exports each year were about 50 000 t in the 1960s and 1970s, accounting for nearly 10% of the world trade in shelled groundnut. Average shelled groundnut export each year from 1981 to 1985 increased to 165 000 t, representing about 20% of total world shelled groundnut trade. Shelled groundnut export has increased to 200 000 t to 300 000 t since 1986 (Duan Shufen and Yang Wenguang 1989). There were some changes from exporting only shelled groundnut to exporting processed groundnut products. Shandong Province alone produced 60 000 t of processed groundnut products in the late 1980s, including roasted groundnut pods, fried groundnut seeds, roasted groundnut seeds, and peanut butter (Yu Shanxin 1989).

Factors Affecting Development of Groundnut Production in the 1980s

Policy and Economic Factors

Since the initiation of agricultural reforms in the late 1970s the lands have been managed by farmers in family units, greatly stimulating farmers to increase production. Groundnut is tolerant to drought, can be produced in poor soils, and fits well into crop rotation schemes. Groundnut production is relatively stable and gives higher returns than other crops with less input. With improved marketing facilities, demand for groundnut has remained high. Groundnut for the domestic market and export, for instance, reached 60% of total groundnut production in Shandong Province. The groundnut price remains attractive and stable. These factors have all contributed to increased groundnut production.

Table 4. Comparison of area, production, and yield of groundnut in the People's Republic of China (1970–1989).

Periods	Area ('000 ha)	Cumulative change (%)	Production ('000 t)	Cumulative change (%)	Yield (kg ha^{-1})	Cumulative change (%)
1970–1979	1821	–	2223	–	1219.5	–
1980–1984	2369	30.1	4018	80.7	1697.8	39.2
1985–1989	3112	70.9	5954	167.8	1920.0	57.4
1980–1989	2740	50.5	4986	124.3	1808.8	48.3

Source: China Agriculture Yearbooks.

Introduction of Improved Varieties and Scientific Techniques

Several new groundnut varieties and improved scientific techniques were applied to groundnut production in the 1980s. Cropping systems were changed, plastic film was used for mulching, pesticides were applied, and more use was made of appropriate fertilizers. All these factors greatly stimulated groundnut production.

Adoption of improved groundnut varieties

In the 1980s old varieties were replaced by improved varieties in 95% of the area under groundnut cultivation. Cultivars Fuhuasheng and Baisha 1016 (spanish types) were the major varieties grown in the northern region from the 1960s. They have been replaced by medium maturing Xuzhou 68-4, Haihua No. 1, and Hua 37. The yield of the large seeded Xuzhou 68-4 and Haihua No. 1 can reach 3750 kg ha^{-1}, 15% higher than the yield of the old spanish types on land of moderate fertility. On the basis of surveys conducted in six provinces in 1986 these varieties covered 75% of the area under production (IGGP 1988). Until 1990 new varieties with medium maturity and large seed were grown on 500 000 ha (70% of the groundnut-producing land in Shandong Province) (Hu Xinmin, unpublished data).

Virginia and peruvian group varieties were the main ones grown in the southern region until the 1950s. After the introduction of groundnut protection in autumn and rotation with rice (*Oryza sativa*), the spanish type replaced the old varieties. Improved varieties with early maturity and good agronomic traits (Shanyou 27, Yueyou 116, Yuesuan 58, and Yueyou 92) replaced the spanish varieties in the 1980s.

Newly released varieties in the central region included El Hua No. 4, Furonghuasheng, Tianfu No. 3, Tianfu No. 4, and Luojianjiwo, which are spanish and peruvian types.

It is important to note that bacterial wilt-resistant cultivars Longhua No 3, Hua No 5, Yueyou 92, and the rust-resistant cultivar Shanyou 27 were released to and applied by the farmers in the 1980s. They played an important role in the control of bacterial wilt and rust diseases (Hu Xinmin, unpublished data).

Change of cropping systems and development of summer groundnut in the northern region

One spring crop of groundnut each year was the tradition in the northern region in the past. As the population increased, the demand for grain also increased, and it became necessary to change the cropping system for one of growing more crops yearly. In the 1980s new cropping systems consisting of two crops each year (wheat-summer groundnut) and three crops in 2 years (maize-wheat-spring groundnut) replaced the old cropping systems. This change led to an extension of groundnut-producing areas.

Traditionally groundnut is sown on lands of low fertility. With the introduction of the new cropping systems groundnut can be grown on fertile lands on which wheat (*Triticum aestivum*) was usually grown. Groundnut is a good crop to rotate with wheat – it maintains soil fertility and reduces soilborne diseases of wheat. The summer groundnut area was 100 000 ha in Shandong Province prior to 1984; currently it exceeds 230 000 ha. The average yield of summer groundnut increased from 3580 kg ha^{-1} to 5330 kg ha^{-1} (Guo Zhongguang 1991).

In Henan Province groundnut was of minor importance, accounting for 10-30% of total area. Summer cultivation has increased very fast in Henan in the 1980s to 80% of total arable land in the province. This is an important factor accounting for the increase of groundnut production in Henan Province in the 1980s (Wei Baohua 1991).

Plastic film mulch cultivation

Mulching with plastic film was introduced from Japan in 1978 and was tested in field trials in 1979. At present this technique is applied throughout the groundnut growing regions, especially in the northern region.

Plastic film mulching has the following advantages: it increases soil temperature, maintains soil moisture and good structure, prevents loss of soil nutrition, and enhances development of groundnut root systems and vigorous growth of groundnut plants. Application of this technique has the potential to increase groundnut yield significantly. It also makes it possible to sow groundnut in the early spring when temperatures are low and soil moisture is present for groundnut germination in the northern region. On the basis of surveys conducted in hundreds of groundnut fields in Shandong Province, mulching with plastic film contributed to a 36.6% increase in groundnut yields (Chen Dongwean 1990).

The cost of plastic film has been reduced by 50% since ultrathin plastic film was introduced in 1984. Thus film is now more economical for use by farmers. In 1989, 260 000 ha of groundnut land used plastic film mulching, accounting for 8.2% of the total area under groundnut in the country.

In the central region the plastic film-mulched groundnut is rotated with autumn rice. Yields of mulched groundnut are able to reach 3000 kg ha^{-1}. The overall increase in groundnut production by use of plastic film mulching is estimated to be 1 700 000 t worth some 1.1 billion yua in the 1980s (Sun Yanhao 1990).

Other scientific techniques

Other scientific techniques extended to the farmers in 1980s include narrow bed cultivation, increase of plant density, rational use of fertilizers, and control of insect pests and diseases. These measures have contributed to more efficient management.

Narrow bed cultivation. Narrow bed cultivation helps seedling emergence, and provides for efficient irrigation with better drainage, leading to a 10% increase in pod yields. The technique is currently being used by farmers in the northern and southern regions.

Increase in plant density. For medium maturity large-seeded varieties a density ranging from 240 000 to 270 000 plants ha^{-1}, and for spanish type a plant density of 300 000 plants ha^{-1} are recommended (Huang Xunbei 1991).

Rational use of fertilizer

Organic manure and chemical fertilizer have been increasingly used in the 1980s in many groundnut-growing areas. On the basis of surveys in Shandong Province, 80% of groundnut is grown with assistance from chemical fertilizers. Farmers usually apply 15–30 t ha^{-1} of organic manure, 150–300 kg ha^{-1} of urea, and 750 kg of phosphorus fertilizer ha^{-1} (Guo Zhongguang 1991). The amount and proportion of N, P, and K applied depends on soil fertility, especially in Shandong and Guangdong Provinces (Zheng Huaiyan 1990).

Effective control of groundnut pests and diseases

Early and late leaf spots and rust (*Puccinia arachidis*) are the most important diseases in the People's Republic of China. The application of fungicides in the 1980s helped to reduce losses caused by leaf spots and rust. Other methods of plant protection adopted by the farmers include treatment of seeds with fungicide for control of collar rot caused by *Diplodia* spp and other seedling diseases, spraying with pesticides for controlling aphids, soil application of pesticides to control white grubs (*Leucopholis irrorata*), and treatment of soil with nematicides for the control of nematode diseases (Shou Xiesong, unpublished data).

Progress of Scientific Research

Genetic Resources

In the 1970s, 1577 accessions of cultivated groundnut were collected and maintained. The number of accessions increased to 4354 in 1980s. Most accessions are kept under low temperature for long-term storage.

About 4000 groundnut accessions were evaluated for resistance to early and late leaf spots, rust, and nematode diseases. Some accessions were found to be highly resistant to the above diseases. None of our 1000 accessions tested showed resistance to peanut stripe virus, although some showed low virus seed transmission.

More than 100 accessions of 24 wild *Arachis* species were introduced from the USA, Argentina, and ICRISAT in the 1980s. The nurseries for maintaining wild species of groundnut were set up in Wuhan and Nanning. Resistance of wild species of groundnut to leaf spots, rust, PStV, and bacterial wilt was evaluated. Research on interspecies hybrids is now in progress (Sun Darong 1990).

Groundnut Breeding

Breeding for high yield, resistance, and quality was conducted at the Oil Crops Research Institute, Chinese Academy of Agricultural Sciences, and at various research institutes at the province and prefecture levels in the 1980s. Over 30 improved varieties have been released as follows:

- Varieties with medium maturity and high yield: Yuhua No. 1, Yuhua No. 2, Haihua No. 1, Hua 37, and Jiyou No. 4, etc.;
- Varieties with high yield and early maturity: Xianghua No. 1, Zhonghua No. 1, Tainfu No. 3, Tainfu No. 4, etc.;
- Varieties with early maturity and large seed suited for summer groundnut in the northern region:

Xuhua No. 3, Xuhua No. 4, Longhua No. 8, Longhua No. 9, etc.;

- Varieties with ultra-early maturity: Nouhua No. 1 and RH 381;
- Varieties with good quality: Hua 17, Hua 9, El Hua No. 4, etc.;
- Varieties with high resistance to bacterial wilt: Yueyou 92, Guiyou No. 28, El Hua No. 5, Zhonghua No. 2, and Longhua No. 3; and
- Rust-resistant varieties: Shanyou 27, Shanyou 253, Yueyou 256, etc.

Progress has been made on the research of inheritance of the resistance to bacterial wilt and rust.

Cultural Techniques for High Yield and its Physiology

Studies on the cultural methods to produce high yields were carried out by the universities, research institutes and extension stations in the 1980s. On 600 ha farms 7500 kg ha^{-1} of groundnut was produced in Shandong Province; the highest yield (11 190 kg ha^{-1}) was produced on a small plot of about 0.15 ha. A yield of 7086 kg ha^{-1} was achieved for summer groundnut on 30 ha (Sun Yanhao 1990). The techniques for high yield were demonstrated and transferred to the farmers, thus greatly enhancing groundnut production. In six counties in Shandong Province in 1990 average groundnut yield exceeded 3750 kg ha^{-1} (Guo Zhongguang 1991). To achieve high yields various components were identified including type of crop rotation, plowing, plant density, application of fertilizer, and control of diseases and pests (Sun Yanhao 1990).

Research was conducted on the influence of plant growth regulators for controlling excessive growth of groundnut and to increase tolerance to drought. Treatment of seeds with polyethylene glycol solution to improve vigor and the mechanism underlying the treatment were investigated. The physiology of drought-tolerant varieties was studied. The following aspects have been studied: effect of soil water on the rate of photosynthesis, effect of temperature and shade on growth of groundnut during seedling stage, and computer simulation of groundnut development.

Fertilizers and Nutrition Physiology

The effect of various rates of application of N, P, and K fertilizers on groundnut yields in soils of different fertilities were tested. Appropriate rates were determined based on the soil fertility. Research on boron nutrition and B fertilizer application on groundnut revealed the mechanism of B absorption and accumulation by groundnut and B distribution in groundnut. Effectiveness of application of B fertilizer was negatively correlated with the amounts of soluble B in the soil. Soils with soluble B below 0.4 ppm were considered to be deficient. Below 0.2 ppm B deficiency was severe. B fertilizer applied in the southern region, where soils are not generally deficient in B resulted in 10% increases in groundnut yields. Research on iron deficiency revealed that it was caused by shortage of available Fe in the soil. Application of Fe fertilizer could increase groundnut yields by 20% in soils deficient in available Fe. Groundnut seed sprayed with rare-earths solution in the growing season could increase groundnut yield by 10%.

The response of groundnut to rhizobial inoculation was investigated. Some compatible strains of *Rhizobium* were selected and used for production of liquid and vermiculite mixed inoculants. Inoculants are currently being applied on 84 000 ha and have increased groundnut yields by up to 15% in 205 sites in seven groundnut-producing areas.

Control of Groundnut Diseases and Pests

Early and late leaf spots, virus diseases, rust, nematode diseases, web blotch (*Phoma arachidicola*), and bacterial wilt (*Pseudomonas solanacearum*) are economically important groundnut diseases. Major insect pests of groundnut include white grubs, aphids (*Aphis craccivora*), and bollworm (*Helicoverpa armigera*).

Surveys on the occurrence and distribution of nematode diseases have been carried out in the 1980s. They revealed that *Meloidegyne hapla* in the northern region and *M. arenaria* in the southern region were the major species of nematodes damaging groundnut crop. The life cycle, biological characters, and spread of the nematodes and their control have been studied. Aldicarb, carbofuran, etc., are currently being recommended for the control of nematode diseases.

Nationwide surveys for the occurrence and distribution of groundnut virus diseases have been carried out. Peanut stripe virus, cucumber mosaic virus, peanut stunt virus, and tomato spotted wilt virus are considered to be economically important in the country. Use of virus-free seed, plastic film mulch cultivation, etc., was shown to be successful for the control of cucumber mosaic virus disease in some areas (Xu Zeyong 1987).

Further studies on groundnut isolates of *Pseudomonas solanacearum* showed that they belonged to biotypes 3 and 4. Some different pathotypes and virulent strains were found in some areas. Bacterial wilt-resistant groundnut varieties with good agronomic traits have been released and are being used by farmers. The resistance appears to be stable in most cases (Tan Yujun and Liao Boshou 1990).

Web blotch is a new disease of groundnut in the country. A causal pathogen of the disease has been identified. Some progress has been made on the selection of the media for production of spores of *Cercospora arachidicola, Phoma arachidicola*, and *Leptosphaerulina crassiasca.* Some fungicides were tested and recommended to the farmers for control of foliar fungal diseases.

On the basis of the surveys the predominent species of white grubs were determined in different areas. Progress had been made on studies of their life cycle and control. Aldicarb, carbofuran, and methylisofenphos were tested and recommended for control of white grubs. Research on biological controls of white grubs is in progress (Shou Xiesong, unpublished data).

Major Constraints to Groundnut Production

Although groundnut production developed rapidly in the People's Republic of China in the 1980s, its development in the different regions and areas is unbalanced. Groundnut in most areas is less developed and yields continue to be low. The following constraints were identified in these areas.

Drought

Drought is the most important constraint to groundnut production. Since groundnut is usually grown on the highlands on sandy soils with low fertility without irrigation, production depends largely on the rainfall during the growing season. Average annual rainfall in the northern region is about 700 mm and is adequate for growing groundnut. In some years when rainfall is less than 500 mm, drought occurs. Drought in the northern region is often accompanied by heavy infestations of aphids that lead to epidemics of virus diseases and severe reductions in yield. Although annual rainfall is 1500 to 2000 mm in the southern region, uneven distribution can result in drought conditions, especially when temperatures are high (Zheng Huaiyan 1990; Liu Zeyi 1991).

Low-fertility Lands

Groundnut is often sown on the highlands and in sandy soils along river basins, where soil fertility and water-holding capacity are low. Even in Shandong Province where conditions are better for groundnut cultivation, 70% of groundnut is currently grown in highlands in the hilly areas. Irrigated land under groundnut is less than 200 000 ha in Shandong Province (Chen Dongwen 1990). Nearly 70% of groundnut is grown in sandy and light sandy soils along the river basin in Henan Province (Wei Baohua 1991). In Guangdong and Guangxi Provinces two-thirds of groundnut is grown on the highlands, 50% of which has poor fertility. Groundnut yields in this region do not generally exceed 1100 kg ha^{-1} (Zheng Huaiyan 1990).

Successive Sowing

Groundnut is grown in three major regions. In the large groundnut-growing areas groundnut covers 30% to 50% of the total arable land. Since groundnut cultivation is usually limited to highlands and sandy soils it is difficult to adopt crop rotation methods. In Henan Province over 70% of groundnut is grown conti-nuously as a sole crop (Wei Baohua 1991). Leaf spots, nematode diseases, and white grubs become severe under these conditions. The tests in Shandong Province showed that continuous sowing of groundnut reduced yields by 20 to 30% compared with the groundnut grown under rotation with other crops (Sun Yanhao 1990).

Pest and Disease Problems

No effective measures are currently available for the control of groundnut virus diseases, which cause severe reductions to yield during epidemic years. At present no resistant sources for nematode diseases have been identified, although nematodes can be controlled by applying nematicides. Leaf spots, rust, web blotch, and white grubs, although regarded as serious problems in some areas, are not being effectively controlled.

Management

Poor management and low inputs continue to be a constraint for groundnut production in many areas.

Prospects for Improving Yields

The People's Republic of China contains 22% of the world's total population but only 7% of the world's total arable land. As its population increases so does the demand for grains. Food crops compete with other crops for the limited arable land available. After its rapid increase in the 1980s, the area under groundnut has stabilized at 3.0 to 3.3 million ha. No substantial increase in area is expected in the years to come. According to plans for groundnut production in Shandong and Guangdong Provinces, groundnut sowing area will be stabilized at the present level over the next 10 years (Guo Zhongguang 1991; Zheng Huaiyan 1990).

Production and market demands are favorable to stabilization of groundnut-sown area. At first, increase of groundnut production closely followed the increase in total agricultural production in the country in the 1980s. For instance, major agricultural products, grains, cotton, and groundnut had all increased on a per capita basis in Shandong Province in the 1980s. Secondly market demands for groundnut continued to be high. Experts assessed that demands for groundnut from the domestic and international markets continued to be high. Experts assessed that demands for groundnut from domestic and international markets and consumption for cooking oil were 2 700 000 t, whereas total production is only 2 000 000 t at present. Shandong Province is planning to increase production to 2 600 000 t of groundnut by the year 2000. If a yield increase from 2955 kg ha^{-1} in 1990 to 3855 kg ha^{-1} in 2000 is achieved, demand for groundnut will still be unfulfilled. It is quite apparent that to increase groundnut production, it will be necessary to stabilize groundnut area and focus on increasing groundnut yield.

The strategy for increasing groundnut yield is to make more efforts to develop the production in the areas with low yield; these include Henan, Hebei, Guangdong, Guangxi, and Liaoning Provinces. In those areas groundnut yields are below 1500 kg ha^{-1}. For improvement of groundnut production in these areas it is necessary to better understand various constraints to groundnut production and measures to be taken by government agencies to overcome these constraints. These will include strengthening of research and extension arms of the government.

Further increase in groundnut yields in the provinces of Shandong and Jiangsu will be attained only by adopting high input technology, coupled with computer modeling, and the use of more irrigated land for production.

Acknowledgments

Sincere thanks are given to Drs Sun Darong, Yu Shanxin, Duan Naixuo, Wan Yurond, Zhang Xuejiang, Cai Chougbe, and Chen Jun for their advice and comments.

References

Chen Dongwen. 1990. Review of groundnut production development in Shandong Province. Peanut Science and Technique 1:12-14.

Duan Shufen, and **Yang Wenguang.** 1989. Prospects of world groundnut production and trade. Pages 1-13 *in* Proceedings of the First National Groundnut Conference, 7-10 Nov 1989, Qingdao, People's Republic of China.

Guo Zhongguang. 1991. Situation of groundnut production and techniques available for its further development. Peanut Science and Technique 2:20-23.

Huang Xunbei. 1991. The ways for improvement of groundnut production in highland. Peanut Science and Technique 1:33-34.

IGGP (Inspection Group of Groundnut Production). 1988. Development of groundnut cultivation techniques in six provinces in the northern region and the causes for reduction of groundnut yield in 1986. Peanut Science and Technique 2:16-19.

Liu Zeyi. 1991. Review and prospect of groundnut production in Guangxi Province. Peanut Science and Technique 2:26-29.

Sun Darong. 1990. Review and prospects of groundnut production and research. Oil Crops of China 1:1-3.

Sun Yanhao. 1990. Further development of groundnut production relying on science and techniques. Peanut Science and Technique 2:8-11.

Tan Yujan, and **Liao Boshou.** 1990. Review of studies on groundnut bacterial wilt. Oil Crops of China 4:87-90.

Wei Baohua. 1991. Summer groundnut planting before harvest of wheat in Henan Province. Peanut Science and Technique 1:16-21.

Xu Zeyong. 1987. Groundnut virus diseases in China. Oil Crops of China 3:73-79.

Yu Shanxin. 1989. Review of studies of integrated application of groundnut and its by-products. Pages 143-156 *in* Proceedings of the First National Groundnut Conference, 7-10 Nov 1989, Qingdao, Peoples' Republic of China.

Zheng Huaiyan. 1990. Importance of oil crop production for food supply and strategy for its development in Guangdong Province. Peanut Science and Technique 1:29-31.

Regional Review – Australasia

K.J. Middleton[1]

Abstract

*Groundnut (*Arachis hypogaea*) production in the Australasian region is small by world standards, but in the past it has provided a significant amount of high quality groundnuts for world trade during the off-season for northern hemisphere production. Nevertheless production in Australia is influenced by both technical problems and marketing difficulties, which interact to some extent.*

Technical advances include breeding and introduction of cultivars with higher yields, refinement of strategies for foliar disease controls to reduce the cost of fungicides, enhanced understanding of crop physiology especially drought alleviation, selection of effective seed dressings, efficient management of aflatoxin contamination, economical ways of weed control, sustainable land management, introduction of a seed production scheme, a move towards irrigated production to stabilize the industry, adoption of computer-based on-farm decision making, and development of efficient drying and harvesting procedures.

Plans for major industry restructuring, currently under consideration, are expected to alleviate past marketing difficulties. Changes proposed include an industry-controlled pool system as has previously operated, but also include a commercial marketing arm that contracts to purchase directly from growers as well as the pool intake.

Résumé

***Revue régionale—Australasie:** La production d'arachide (*Arachis hypogaea*) dans la région d'Australasie est faible à l'échelle mondiale, mais elle a fourni dans le passé une quantité importante d'arachide de haute qualité pour le commerce mondial pendant la saison morte de la production en hémisphère nord. Néanmoins, la production en Australie est influencée tant par des problèmes techniques que par des difficultés de commercialisation, qui chevauchent à certains égards.*

Des progrès techniques comprennent la sélection et l'introduction de cultivars à rendement élevé, la mise au point de stratégies pour la lutte contre les maladies foliaires afin de réduire le coût des fongicides, une meilleure compréhension de la physiologie de la plante, particulièrement pour amoindrir les effets de la sécheresse, la sélection d'enrobages efficaces des semences, une gestion efficace en cas de contamination par les aflatoxines, des méthodes économiques de désherbage, une gestion durable du sol, l'introduction d'un système de production semencière, un progrès vers la production irriguée pour stabiliser l'industrie, l'adoption d'un système de prise de décisions assisté par ordinateur à l'exploitation et le développement de procédures de récolte et de séchage efficaces.

Les plans d'une restructuration profonde de l'industrie qui sont actuellement envisagés, permettraient de réduire les difficultés de commercialisation subies dans le passé. Les changements proposés comprennent un système de mise en commun de l'industrie, ainsi qu'il a été effectué dans le passé, mais aussi un organe commercial pour la commercialisation qui conclut des contrats pour acheter directement auprès des cultivateurs ainsi que des livraisons de la mise en commun.

---

1. Formerly Principal Plant Pathologist, Queensland Department of Primary Industries, J. Bjelke-Petersen Research Station, P.O. Box 23, Kingaroy, Queensland 4610, Australia.

Middleton, K.J. 1992. Regional review – Australasia. Pages 167–171 *in* Groundnut – a global perspective: proceedings of an international workshop, 25–29 Nov 1991, ICRISAT Center, India (Nigam, S.N., ed.). Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

For the purposes of this review, Australasia is defined as Australia, New Zealand, Papua New Guinea, and the numerous island countries within the South Pacific. Of these countries, Australia is the only one to have groundnut production of a size significant to the local economy. Although small producers by world standards, one significant aspect of Australasian production is that Australian producers can offer supplies to the world market at a time when the major producers cannot offer fresh product.

Australia

The Australian groundnut industry represents only 0.2% of world production, and as a consequence is forced to accept world price variations. However, the industry has significant substance for those involved, as it accounts for 2.5% of total gross primary production in the state of Queensland (for the period 1981/82–1990/91), in competition with major commodities such as sugar, wool, and wheat (*Triticum* spp) where Australia is a significant contributor to world trade. The Australian industry is heavily dependant on mechanization with little hand labor.

Australian groundnuts could be used to satisfy Australian domestic consumption and to meet international demand at the time of year when they are available and other countries cannot supply.

However, groundnut production in Australia is decreasing, whether measured in terms of area, number of growers, or total productivity. Yields have been declining, and are substantially lower than world competitors. In part, this has been due to a consistent pattern of adverse seasonal conditions that have had significant impact on dryland productivity. There is potential for increased yield through variety improvement, disease control, and drought alleviation, and there also exists the opportunity to expand the production area. Additionally there are no restrictions on groundnut production in Australia, and the entire crop can be sold.

Surely, then, it is reasonable to ask why Australian growers are not meeting this challenge. The major constraint at present is the reliance on dryland (rainfed) production, using cultivars not well adapted to these conditions. A second constraint is the current marketing structure of the Australian industry, which suffers from both fragmentation and some of the disadvantages of the statutory authority put in place to (unsuccessfully) overcome this fragmentation. Obviously, these two constraints differ significantly – one is a technical matter, presumably open to redress by research, while the other is a socioeconomic problem.

Research on groundnut problems in Australia

Agricultural research in Australia is unique, because the universities play a smaller role than state and federal public research agencies. As the groundnut industry in Australia is largely confined to the state of Queensland, the largest part of public research into the problems confronting the industry are conducted by the Queensland Department of Primary Industries, with limited research within the University of Queensland and by the Commonwealth Scientific and Industrial Research Organisation. Part of this research is funded entirely from the public purse, but most is conducted by scientists paid from the public purse, whose operations are paid using industry levies with matching government support. The industry also conducts some research of a practical nature, and these four institutions regularly collaborate to resolve the technical problems of the industry.

Constraint alleviation has been successful in several areas.

- Varietal improvement has been undertaken since 1977–78, when the Department appointed the first groundnut breeder, although some testing of introductions had been undertaken earlier. To date, only one cultivar bred in Australia has been released from the breeding program; this is a spanish type suited to local market requirements (named McCubbin). Breeding of virginia types, however, is the priority area as these types are currently required for approximately 85% of the Australian market. The breeding program has set goals for yield improvement, quality (particularly keeping quality), maintenance, and resistance to early leaf spot (*Cercospora arachidicola*), late leaf spot (*Phaeoisariopsis personata*), and rust (*Puccinia arachidis*) diseases. In parallel to the hybridization program, variety improvement through introduction and testing under local conditions is vigorously pursued. Introductions successful under local production conditions include Shulamit and NC 7.
- Foliar disease control by the use of fungicides has been refined since the use of benomyl commenced in the early 1970s. A larger range of fungicides is currently available. They vary markedly in mode of action, and the incidence of disease varies from location to location and from season to season. In addition, diseases not recognized in the early 1970s

are now regularly seen, and contribute to yield losses. The industry is moving towards strategic use of fungicides, aiming at the maximum benefit for minimal cost and risk.

- Better understanding of the importance of good land management through crop rotation, minimum tillage, stubble retention, etc., has followed the perception that such practices can help to control soilborne fungi, and can aid in water infiltration and storage for use during the growing season. Included in land management improvements is the practice of better fertilizer decision making, through integrated use of farm records and soil tests.
- The management of aflatoxin, a regular consequence of drought during groundnut production in Australia, has been recognized as an example for others to follow. The industry is able to supply high quality product to its customers even in years when aflatoxin contamination is high (calculated on the proportion of contaminated deliveries). It achieves this by testing of deliveries upon presentation, and segregation of those containing aflatoxin. By careful detection of discolored kernels, in most cases the contamination can be removed, leaving the bulk of the crop below the acceptable levels of aflatoxin in Australian food, as defined by regulation. However, this management program is expensive, and alternative methods of prevention of aflatoxin contamination are under investigation.
- Weed control has, in recent years, suffered from the loss of the widely used herbicide Dinoseb. However, paraquat has been identified as an effective alternative, and offers similar weed control for less cost than Dinoseb. Adoption of band spraying of herbicides (over the row) can assist further in reducing production costs and the reduction of the herbicide impact on the environment. Control of volunteer groundnuts in fallow or in alternative crops is a major constraint to the adoption of reduced-till farming practices by groundnut growers.
- Cost-efficient artificial drying procedures compatible with equipment commonly used to store and transport groundnuts in Queensland have been developed and widely adopted by growers. These practices are especially important in the wetter production areas of north Queensland, where the harvest season frequently coincides with the end of the wet season. Harvest machinery better adapted to these conditions is also under development.
- The benefits of fungicidal seed dressings was demonstrated in Queensland several decades ago, and all seed sold is now treated with a mixture of fungicides to minimize seedling losses and crown rot. While the community trend is away from the use of pesticides, treatment of seed is a sound practice from both economic and environmental standpoints. The industry has used a mixture of quintozene and captan for many years, but recently captan has been replaced with Dichlorofluanid.
- A tougher line has been taken in recent years over the residues of persistent insecticides for the control of soilborne insects. A program aimed at biological control of these pests is showing promise.
- The industry has existed for over half a century without a structured seed production system. The shortcomings of this practice have now been recognized, and a seed production scheme for the widely grown cultivars has now been implemented. This scheme aims to provide seed of high quality and genetic purity.
- Australian groundnut production, in rotation with crops such as maize (*Zea mays*), requires the use of lime and artificial fertilizers. Use of these increasingly expensive inputs has been refined by the use of computer-based decision making systems, using well-defined relationships between soil test results and crop response for the different soil types supporting groundnut production.
- The industry is showing unmistakable signs of moving towards irrigated production areas, although the traditional dryland production areas are not expected to abandon the crop but rather lessen the frequency of this crop in the rotation system adopted. This combined change is expected to lead to increased total production, as well as to add to the stability of the industry in two ways. The production from irrigated areas should not be subject to the same variation from year to year as in the dryland areas, and in the traditional areas, the improved soil conditions resulting from less-frequent legume (groundnut) production should stabilize production from these areas whenever groundnuts are grown.
- The industry has adopted a policy of utilizing new cultivars and new production areas, with new production technologies as necessary to facilitate their acceptance by growers. It is anticipated that this policy will help stabilize production in the future.
- However, there are still some technical problems not well resolved by research. There remains scope for improved yield performance and foliar disease control. The soilborne diseases, cylindrocladium black rot, sclerotinia blight, and lasiodiplodia pod rot, still cause significant losses to production. Drought still causes major losses to both quantity and quality of production.

Australian groundnut scientists have become significantly involved in the international research scene, through collaboration with scientists from Indonesia, ICRISAT, USAID projects and the Peanut CRSP, the Netherlands ATA 272 project, the People's Republic of China, Malaysia, the Philippines, and others, supported by grants from the Australian Centre for International Agricultural Research (ACIAR) (see pp. 193-204, these Proceedings) and Australian International Development Assistance Bureau (AIDAB) Special Purpose Grants to the Consultative Group on International Agricultural Research (CGIAR) Centers.

Attempts to redress the socioeconomic problems

Marketing of groundnuts in Queensland legally has always been the sole prerogative of the Peanut Marketing Board, established in 1924 to support the production of the crop through an orderly marketing system. The purpose of this statute was to compel all producers of groundnut in Queensland to buy seed and to market the produce through one central body, to prevent competition among the growers. This statute was enacted at the request of the growers of the day. The Board is controlled by a group of growers, representing the growers' interests. Part of the statute's conditions included a requirement that the crop was marketed as a 'pool', that is, growers were paid after all produce was sold, costs of preparation for sale deducted, and at an average price with some adjustment for quality. However, some advance against the anticipated final return is paid soon after delivery. The Board was also compelled to undertake the marketing of all 'marketable' groundnuts presented by growers. Large crops resulted in somewhat lower returns for every producer, as the production in excess of domestic consumption could be exported at world (usually lower) prices; similarly, small crops (due to drought, for example) resulted in reduced return to growers as the industry was forced to maintain a shelling and processing plant of sufficient size to handle the bumper crop, yet in dry seasons the limited throughput raised the cost of preparation for sale, considered on a tonnage basis.

'Independent' shellers became established, circumventing the statute by selling interstate to use a clause in the federal constitution that supported free interstate trade. These independent shellers were free of the restrictions under which the Board is compelled to operate, notably compulsory acquisition and the pool system, and as a result have been able to offer growers better prices and earlier payment than those offered by the Board. The increasing share of the crop passing through the independent sheds compounded the problem of the high cost of processing smaller crops, and has been further compounded by the series of dry years that reduced total crop size. These problems added to grower dissatisfaction with the returns from groundnut production.

The industry saw only two possible ways of increasing grower support: one was to enforce the compulsory acquisition powers already included in the statutes in place, and the other was to commercialize, using a new structure. The latter seems to be preferable.

A new structure has been proposed and generally accepted by growers to take advantage of the board structure, but remove its disadvantages. This is still very much in a state of flux, but the industry is now undergoing significant restructuring. By the time of the workshop, further progress towards stabilizing the industry through changes in the marketing structure could be better defined.

The advantages of the past system are:

- It is controlled by growers;
- It provides the security of always having a buyer for the crop;
- It sells the crop on behalf of growers at the best prices;
- It treats all growers the same through the pooling system;
- It provides services to the industry (such as field officers, laboratory services); and
- It is monitored by the government.

However, the disadvantages are:

- The compulsory acquisition powers have not been enforced, affecting grower returns;
- It cannot raise equity funding;
- It cannot make price contracts with individual growers, in contrast to independent shellers;
- It does not run on normal commercial principles, as maximum return for an individual grower in not its chief aim; and
- The government legislation under which it operates restrains its activities.

It is proposed to form a structure with two entities – a cooperative and a company. The cooperative would:

- Be owned by growers;

- Enable a pooling system to operate;
- Provide a forum for growers; and
- Provide grower services.

The company would:

- Be owned by the cooperative and by growers who acquire shares through proceeds of their crop;
- Be run by a board consisting of growers, commercial directors and a staff member;
- Be able to raise equity funding;
- Make price contracts both with individual growers and the cooperative;
- Be run on commercial lines, aiming to be profitable; and
- Come under the jurisdiction of the Australian Securities Commission.

This restructuring, if approved, will enable growers to sell the crop to either the cooperative's pool, the company at a fixed price, or to an independent sheller. The cooperative will receive whatever crop growers wish to place into a pool system, sell its crop to the company according to a predetermined formula, and pay growers in a manner similar to that used by the Board at the moment. The company will enter into a long-term contract to purchase the total intake of the cooperative, may enter into price contract with an individual grower, process and market the crop in a similar way that the Board currently does, and will pay dividends to its shareholders from profits.

Expansion by new growers is proposed through the company undertaking (at cost) the harvesting, drying, and handling of their crop, to enable growers to enter into the industry without the capital cost associated with these operations.

Papua New Guinea

Groundnut production in Papua New Guinea occurs on two scales. Garden production for local consumption occurs throughout the country, but is not organized in any way; similarly, problems associated with this type of production are not under investigation. However, some mechanized production does occur in the Markham Valley, in the northern part of the country. Problems in this type of groundnut production are similar to those in nearby regions.

New Zealand

New Zealand is not a commercial producer of groundnuts, although attempts are under way to develop the capacity to grow the crop for local consumption. New Zealand currently imports almost all groundnuts and groundnut products consumed in the country, at a cost of NZ$ 10 million for groundnuts and NZ$ 0.3 million for oil. Experimental sowings of spanish and valencia types in northern parts of the country have produced yields high enough (approximately 2.5 t ha^{-1}) to encourage production, when the high prices of imported product and oil are considered.

The major constraint to commercial production is the lack of large-scale harvesting equipment, and this constraint is likely to remain until production increases, or some advance is made in technology to encourage sufficient sowing to justify this machinery. The type of advance likely to trigger this adjustment is the importation of high-yielding short-season cultivars, and this avenue is being pursued.

Fiji

Groundnut production in Fiji is limited, with annual production ranging from 100 t to 450 t during the last 5 years. Importations are extremely limited.

Groundnuts are seen as a valuable component of the diverse crop production recognized as desirable for that country. Two spanish type cultivars with 115–125 days to maturity are grown. Short-season cultivars are not seen as a requirement for production under Fijian conditions. Mineral fertilizers, herbicides, insecticides, and fungicides are used as needed.

Testing of introduced cultivars for high yield potential and resistance to common diseases is seen as a priority area, and investigation of fertilizer needs on various local soil types is also in hand. The testing of introduced varieties for Fijian conditions is aided by cooperation with international research organizations.

Acknowledgments

Compilation of this report has only been possible through the cooperation of many of my friends and colleagues from the Queensland Department of Primary Industries, of Mr P. Hatfield and others from the Peanut Marketing Board, Australia, the Ministry of Primary Industries and Cooperatives in Fiji, Dr J. Anderson of the Department of Scientific and Industrial Research in New Zealand, and Dr J. Mandich in Papua New Guinea. Their assistance is sincerely appreciated.

Discussion

S. Thangavelu: I understand there is a system of storing groundnut for seed use in the form of seed in Myanmar without any loss of viability. What is the method of storage?
P.S. Reddy: Groundnut for seed use in Myanmar is stored only in the form of pods.

Z.A. Chiteka: Groundnut is an important crop in South Asia. You mentioned that seed availability is a problem. We also find a similar problem in the SADCC region. Would you like to comment on the reasons why this problem is persistent, and what efforts have been or are being made to solve this problem?
P.S. Reddy: The seed industry does not find it profitable to take up seed production of groundnut in India because of its low multiplication turnout. Considering the high investment for seed, farmers also generally keep their own seed. A scheme has been proposed to the Government of India which, when implemented, might solve the groundnut seed problem in the country.

Maqsood Ahmed: In Pakistan, the price of groundnut fluctuates considerably. How is price regulated in India?
P.S. Reddy: Groundnut prices in India are regulated by a government intervention mechanism called 'Support Price'. Each year the government announces in advance a support price for major agricultural commodities. Whenever free domestic market price falls below the declared support price for a commodity, the government buy the produce from farmers. In cases where the free market price rises too high, the government intervenes by importing the commodity or its products.

N.B. Essomba: You reported some interesting *Bradyrhizobia* strains from Vietnam and Thailand. I would like to know how these strains are inoculated and how successfully they have been extended to farmers?
S. Jogloy: *Bradyrhizobia* are inoculated either through seed or are directly spread on the seedbed at sowing. It was observed that the response to these inoculants was better in wetlands than in uplands. This technique is still in the experimental stage and no large-scale extension has been tried so far.

Z.A. Chiteka: You quoted average yields of 3–4 t ha^{-1} in farmers' fields in Malaysia. These yield levels appear to be very high considering the constraints you listed. Would you like to elaborate? Secondly, you cited some cultivars, UPL PU 6 and UPL PU 8, as resistant to leaf spot. Are these resistant to early leaf spot or late leaf spot?
Zainab Ramawas: The yields in Malaysia are considered on a fresh weight basis, as the groundnuts are processed within 48 hours of harvest. On a dry weight basis, we may get about 1.7 t ha^{-1}.

R.M. Abilay: UPL PU 6 and UPL PU 8 are resistant to late leaf spot in the Philippines.

Z.A. Chiteka: What methods are used in screening for resistance to aflatoxin?
S. Jogloy: The dry seed resistance technique is used for screening for resistance to *Aspergillus flavus*.

M.B. Syamosonta: What is the main effect of soil acidity in Southeast Asia? Is it calcium deficiency? Or is it Al toxicity or is it the K:Ca ratio or the interaction of these?
S. Jogloy: Soil acidity causes high levels of aluminium, manganese and low levels of phosphorus, calcium, magnesium, and molybdenum.

Ousmane N'doye: Shade is a constraint to groundnut production in the Philippines. Can you comment on the research progress towards solving this problem?
S. Jogloy: Screening for shade-tolerant lines has resulted in the identification of four lines which are currently in the advanced stage of testing.

M.S. Basu: Most of the soils in Southeast Asia are acidic (4.5–6.5 pH). Do you face any problem on the application of gypsum in acid soils? What is the source of N-fertilizer used in acid soils of Southeast Asia?
S. Jogloy: Gypsum application is rarely done by farmers in Indonesia. The recommended dose of liming is 0.5–2 t ha^{-1} depending on the levels of soil pH. The source of N is urea.

M.S. Basu: What is the extent of yield loss due to peanut stripe virus in Indonesia? How do you organize disease-free seed production commercially?
S. Jogloy: PStV can cause 50–60% yield loss in Indonesia depending on the variety, season, and the crop stage of disease infestation. We do not have any scheme for obtaining virus-free seeds.

Naazar Ali: What is the crop rotation followed in Thailand and how does groundnut fit in the cropping system?
S. Jogloy: Groundnut is sown as a relay crop with maize.

S. Desai: In Indonesia, the spacing adopted is 15 × 15 cm with a seed rate of 50–60 kg ha^{-1}. Does it imply that the seed used for sowing is of very small size? With such close spacing, how are various crop management practices followed?
S. Jogloy: In Indonesia, groundnut is sown by farmers using a dibbling stick, hand hoe, or animal-drawn plough. Plant population varies from 200 000 to 500 000 plants ha^{-1} and a common spacing of 30 × 15 cm or 30 × 20 cm is followed. Seed rate varies from 50 to 90 kg ha^{-1} depending on sowing method. However, the general recommendation of plant spacing is 40 × 10 cm with one seed $hill^{-1}$ or 40 × 20 cm with two seeds $hill^{-1}$.

K.S. Vara Prasad: Is bacterial wilt in Indonesia seed transmissible? If so, to what extent?
S. Jogloy: According to the studies conducted by Dr Mahmoud in Indonesia, the seed transmission rate of bacterial wilt is about 5%.

P.S. Reddy: What is the cost effectiveness of the use of plastic mulch in groundnut production? Is it biodegradable? Do you have any literature on plastic mulch?
Xu Zeyong: The yield increase with plastic mulch is 30–50%. So it is very cost effective. Plastic mulch is not biodegradable. Farmers use fresh plastic sheeting each time. Chinese literature is available on the use of plastic mulch in groundnut production.

P.S. Reddy: What is the technology used in Shandong Province to obtain 7–9 t ha^{-1} pod yield and what is the crop duration?
Xu Zeyong: Selection of a high-yielding variety together with high-input technology, including use of plastic mulch, is the important reason for realizing very high yields. The duration of the crop was about 130–140 days and the botanical type used was virginia bunch.

C.P.S. Yadav: Are white grubs distributed throughout China? What is the extent of damage and what are the control measures?
Xu Zeyong: They are distributed throughout the provinces of northern and southern China. The extent of damage is up to 90% under pest-favorable conditions. We use chemicals to control the grubs.

G.Y. Reddy: During 1987 the average yield recorded in China (2040 kg ha^{-1}) and Japan (2031 kg ha^{-1}) was the highest in these countries in many years; and then there was a fall in productivity. What is the reason for this high yield in 1987?
Xu Zeyong: Favorable weather and even distribution of rainfall in the crop season were the main reasons for recording highest yields.

P.S. Reddy: Can you comment on biological control of white grub?
K.J. Middleton: Biological control of white grub is being tried using *Metarhizium* species.

S. Desai: You mentioned something about the Australian system of aflatoxin management, which even USA wants to adopt. Will you please elaborate on the modalities of the system?
K.J. Middleton: The system of managing aflatoxin in Australia is designed in such a way that the produce is tested at various stages for the presence of toxins in a scientific way and only toxin-free seeds are marketed after grading.

Donor Reports

The Role of FAO in Research and Production of Groundnut

N. Chomchalow[1], C.R. Pineda[2], and E. Kueneman[2]

Abstract

The Food and Agriculture Organization of the United Nations (FAO) has a rather limited role in groundnut research and production, particularly after the establishment of ICRISAT. However, since 1980, FAO has been assisting the National Agricultural Research Systems (NARS) in obtaining information on production technology and genetic material, and in conducting adaptive research at different locations in Africa and Asia.

In Africa, two projects are currently being conducted. The one in Madagascar, concerns with production and consumption of groundnut as oil. The project provides services of two experts, several consultants, some equipment, and funds for training scientists in NARS and farmers. Encouraging results have been obtained within 2 years of initiation of the project. The second project in Zambia focuses on groundnut varietal improvement to obtain high yield, to incorporate resistance to diseases and pests, and to provide packages of cultural technology to the small farmer.

In Asia, FAO's role is to execute United Nations Development Programme (UNDP)-funded regional projects, RAS/82/002 and RAS/89/040. The major objective of these projects is to increase production of food legumes (including groundnuts) and coarse grains. To accomplish this goal the first step is to establish a network of national institutions, linking them with international institutions capable of coordinating research and extension activities for 10 to 14 participating countries. Both the projects facilitated various forms of training and exchange of germplasm, materials, information, and technology. The second project also deals with transfer of technology, postharvest technology, socioeconomics, and potential of under-exploited crops.

FAO is currently formulating a number of projects to improve groundnut production for small farmers. One project is on sustainable cultural management systems where several agronomic and socioeconomic studies are proposed to solve the various regional problems encountered by small farmers. The second project relates to the establishment of a center for dissemination of up-to-date and useful information on groundnut research and production to groundnut workers, including farmers; it also strengthens existing groundnut research networks by facilitating exchange of information among networks.

Résumé

Le rôle de la FAO pour la recherche et la production d'arachide: *L'Organisation des Nations Unies pour l'alimentation et l'agriculture (FAO) n'a qu'un rôle restreint pour la recherche et la production arachidières, particulièrement depuis la création de l'ICRISAT. Toutefois, depuis 1980, la FAO a aidé les systèmes nationaux de recherche agricole (NARS) à se procurer des informations sur la technologie de la production et le matériel génétique, ainsi qu'à entreprendre des recherches d'adaptation en différents lieux en Afrique et en Asie.*

1. Regional Plant Production Officer, Food and Agriculture Organization of the United Nations (FAO), Regional Office for Asia and the Pacific, Maliwan Mansion, Phra Atit Road, Bangkok 10200, Thailand.

2. Agricultural Officer (Industrial Crops) and Agricultural Officer (Food Crops), Food and Agriculture Organization of the United Nations (FAO), via delle Terme di Caracalla, 00100 Rome, Italy.

Chomchalow, N., Pineda, C.R., and Kueneman, E. 1992. The role of FAO in research and production of groundnut. Pages 177–185 *in* Groundnut – a global perspective: proceedings of an international workshop, 25–29 Nov 1991, ICRISAT Center, India (Nigam, S.N., ed.). Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

En Afrique, deux projets sont actuellement en cours. Le premier, à Madagascar, concerne la production et la consommation d'arachide sous forme d'huile. Le projet fournit les services de deux experts, plusieurs consultants, des équipements et des fonds pour former des scientifiques des programmes nationaux de recherche agricole et des cultivateurs. Des résultats encourageants ont été obtenus au cours des deux années après la création de ce projet. Le deuxième projet, en Zambie, se concentre sur l'amélioration variétale de l'arachide pour obtenir un meilleur rendement, pour incorporer la résistance aux maladies et aux insectes ravageurs et pour fournir des technologies culturales au petit cultivateur.

En Asie, le rôle de la FAO est de réaliser les projets régionaux financés par le Programme des Nations Unies pour le développement (PNUD), le RAS/82/002 et le RAS/89/040. Le principal objectif des ces projets est d'accroître la production de légumineuses à grain (y compris l'arachide) et de céréales secondaires. Pour parvenir à cet objectif, la première étape consiste a établir un réseau d'institutions nationales en les reliant avec les institutions internationales qui peuvent coordonner les activités de recherche et de vulgarisation pour les 10 à 14 pays participants. Les deux projets ont permis diverses formes de formation et l'échange de ressources génétiques, d'équipements, d'informations et de technologies. Le deuxième projet porte aussi sur le transfert de technologie, la technologie post-récolte, les aspects socio-économiques et le potentiel de cultures sous-exploitées.

LA FAO formule actuellement un certain nombre de projets pour améliorer la production arachidière des petits cultivateurs. Le premier porte sur des systèmes de gestion culturale durables où des études agronomiques et socio-économiques sont proposées pour résoudre les divers problèmes régionaux subis par les petits cultivateurs. Le deuxième projet prévoit la création d'un centre pour diffuser des informations utiles et à jour sur la recherche et la production arachidières pour tous ceux qui travaillent sur l'arachide, y compris les cultivateurs; il renforce aussi les réseaux existants de recherche arachidière en facilitant les échanges d'information.

Groundnut (*Arachis hypogaea*) is one of the most important oilseeds grown in tropical and subtropical countries. In 1990, total world production was estimated to be 23.1 million t, ranking second only to soybean (*Glycine max*) (107.8 million t in 1990). It is a more important food source than soybean in many parts of the tropics, especially in India and West Africa.

Groundnut is cultivated in both developed and developing countries (at a proportion of about 1:20). The Food and Agriculture Organization of the United Nations (FAO) Production Yearbook for 1989 indicates that 936 000 ha are sown to groundnut in developed countries and 19 157 000 ha are sown in developing countries. Average yields are about 1000 kg ha^{-1} (groundnut in the shell) in developing countries and 2250 kg ha^{-1} for developed countries.

The FAO-executed Projects (1981–1991)

FAO has been providing assistance to groundnut research and production, particularly to those projects and programs directed to small holdings. Groundnut received more attention from FAO in the period preceding the establishment of the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT).

One fundamental problem in groundnut production is the lack of support to national programs related to adaptive research, extension, and similar activities. Even though basic research is being done in a well-conceived and executed international plan, such as in ICRISAT, there remains the need to transfer this information and genetic material to local production environments.

Some developing countries such as China, India, Senegal, Brazil, Nigeria, and Argentina have strong research programs but lack effective extension programs to transfer the available technology to the farmer.

FAO has been trying to assist with this aspect of the problem, and in the establishment of appropriate adaptive research projects, and, most important of all, the promotion of regional cooperation among developing countries in groundnut research and production. A list of the FAO-executed projects on groundnuts or those having groundnut as a component in Africa and Asia is given below.

Africa

Madagascar

This is a continuation of several activities promoted by United Nations Development Programme (UNDP) and FAO in this country. This 5-year project was started in 1989 with the following objectives:

1. Development of national groundnut production, especially in the provinces of Mahajanga, Toliary, Lak Itasy, Lack Alaotra, and Antsiranana;
2. Development of groundnut production in the east coast, between Sambava and Antalaha;
3. Increase of the national consumption of vegetable oils by 100%; and
4. The formulation of a national system for the financing of groundnut and other oilseed production in Madagascar.

To achieve these objectives the project is providing the services of two groundnut experts from Senegal (for the duration of the project), several short-term consultancies, equipment, and funds for training national experts and farmers. The contribution of UNDP is US$ 2 705 433 and the Government of Madagascar is providing FMG 821 150 000 for 5 years.

Within 2 years, the project has already shown encouraging results. The groundnut producers now have more confidence in the support given to them by the government and production has increased. At the start of the project (1989), national production was estimated to be about 33 000 t. As a result of efforts in this project, production in 1991/92 is expected to reach 38 000 to 40 000 t. It is estimated that 7000 t of groundnut will be used for consumption and for export and the remainder will be used for oil extraction. This project has facilitated the functioning of one oil extraction plant (private) in Tulear. This was lying idle, but it is now being rebuilt and modernized in order to process the expected increase in production of this region.

Zambia

Another example of technical assistance projects was the groundnut breeding project provided to the Eastern Province Agricultural Development Project in Zambia. In this country, groundnuts are a very popular food and nutrition supplement for low income groups. The project was designed to provide a continuous and capable groundnut improvement program that would ensure the availability of high-yielding cultivars of both oil and confectionery groundnuts and packages of cultural practices for small holdings.

The program included training national staff, establishment of a groundnut germplasm collection, development of a multidisciplinary research team capable of providing appropriate techniques, and provision of technical and popular publications to help farmers obtain stable yields. Ten national professionals so far have received training in different disciplines (breeding, agronomy, plant pathology, and entomology). With the cooperation of ICRISAT, African Groundnut Council, and other organizations, over 1600 germplasm collections have been assembled and documented. The library of Msekera Research Station was supplied with important books and periodicals on groundnut research and production. Project staff published several research papers in scientific journals and presented papers at international groundnut scientific meetings. Several improved varieties for oil and confectionery were developed and distributed to farmers. Varieties resistant or tolerant to the main diseases and insects were subsequently developed.

Asia

In 1990 Asia contributed more than 68% of the world's groundnut production of 23.1 million t. China produced 6.56 million t and India produced 7.20 million t (Table 1) accounting for 87.5% of the total production in Asia or nearly 60% of the total world's production.

Project RAS/82/002

During the period 1983–89, an FAO-executed and UNDP funded project, RAS/82/002, entitled "Research and Development of Food Legumes and Coarse Grains (FLCG) in the Tropics and Sub-Tropics of Asia" was operated. This project involved Bangladesh, Indonesia, Laos, Nepal, Pakistan, the Philippines, Republic of Korea, Sri Lanka, Thailand, and Vietnam. The project was planned in two phases; the duration of Phase I was 2 years, and activities began in September 1983. The proposed UNDP contribution for this phase was US$ 450 000 and the actual expenditure was US$ 454 394. Phase II was approved in August 1985 and it concluded in June 1989. The UNDP contribution for both the phases was US$ 1 331 453.

Table 1. Groundnut production, area harvested, and yield in project RAS/89/040 member countries.

	Production ('000 t)			Area harvested ('000 ha)			Yield (kg ha^{-1})		
Country	1980	1990	Annual average GR[1]	1980	1990	Annual average GR[1]	1980	1990	Annual average GR[1]
Bangladesh	30	42	5.9	26	32	3.4	1 154	1 304	2.5
China	3 686	6 563	6.0	2 390	3 085	3.2	1 542	2 127	2.7
India	5 005	7 200	3.3	6 801	8 000	1.6	736	900	1.7
Indonesia	783	919	3.0	506	628	2.8	1 547	1 463	0.2
Laos	8	6	-5.6	11	7	-7.9	740	981	2.5
Malaysia	16	5	-16.7	7	1	-18.1	2 422	3 615	1.7
Myanmar	342	459	1.1	456	524	0.5	751	876	0.6
Nepal	-[2]	-	-	-	-	-	-	-	-
Pakistan	57	82	1.0	47	72	2.9	1 234	1 139	-1.9
Philippines	50	35	-0.9	55	50	-0.3	905	695	-1.2
Republic of Korea	13	29	11.9	12	12	4.3	1 058	2 504	7.3
Sri Lanka	7	6	-1.6	12	7	-5.2	590	786	3.8
Thailand	129	162	1.9	100	124	1.0	1 291	1 312	0.9
Vietnam	95	210	9.3	106	220	8.3	895	995	0.9
Asia-Pacific	10 325	15 784	4.2	10 604	12 812	2.0	974	1 232	2.1
Rest of World	6 575	7 322	1.2	7 558	7 156	-0.3	870	1 032	1.5
World	16 901	23 109	3.1	18 163	19 968	1.1	931	1 157	2.0

1. Percentage of annual average growth rate 1980–1990.
2. Data not available.
Source: FAO 1991a.

The long-term objective of the project was to increase production of FLCG in the participating countries in order to bridge the gap between the demand for protein-rich food for domestic needs and export markets and the actual production. One of the main goals of the project was to establish a network of national institutions, linked with international institutions capable of advancing the relevant development objective of participating countries through coordinated research and extension activities. At the completion of the project:

- Ten National Coordinators have been nominated by their respective governments to serve as focal points for the network in their countries.
- A National Coordination Committee has been established in each of the ten participating countries to formulate and review the activities and progress of R&D programs at the country level.
- Six technical Working Groups have been established.
- A Regional Coordination Committee has been established, consisting of the Regional Coordinator (appointed by the host country of Indonesia), the ten National Coordinators, the six Working Group Leaders, and a FAO representative. This Committee has met once a year to review project activities and recommend follow-up action. The representatives of international agencies and programs in the region [namely, the Australian Centre for International Agricultural Research (ACIAR), the Asian Vegetable Research and Development Center (AVRDC), the Centre for Regional Coordination of Research and Development of Coarse Grains, Pulses, Roots, and Tuber Crops in Humid Tropics of Asia and the Pacific (CGPRT), the Centro Internacional de Mejoramiento de Maíz y Trigo (CIMMYT), ICRISAT, the International Development Research Centre (IDRC), and the International Rice Research Institute (IRRI)] were invited to attend the annual meetings as resource personnel. Through these representatives, the project developed excellent linkages with their respective institutions. Such linkages, among other things, were effective in preventing duplication of work.

In order to be better able to undertake research and production programs on FLCG at country level, the project provided training of various forms for scientists and extension workers from participating countries including:

- Eleven short-term training courses;
- Three in-service training courses;
- Two workshops;
- One consultant's meeting; and
- Five study tours.

Details of training activities involving groundnuts are presented in Table 2.

The second major activity of the project involved the exchange of germplasm. This includes exchange of promising varieties, exchange of rhizobium strains, and release of new varieties.

The third activity relates to the exchange of information. Publications were produced as follows:

- Newsletters (eight issues of quarterly semi-technical publication);
- News bulletins (27 issues of biweekly publication); and
- Reports of training courses (14), study tours (5), workshops (2), consultants' meeting, and working group meetings (2).

RAS/89/040

A follow-up project of RAS/82/002, entitled "Regional Cooperative Programme for the Improvement of Food Legumes and Coarse Grains in Asia", funded by UNDP, is being executed by FAO. It became operational in April 1990 and has a termination date of March 1993. Four more countries (China, India, Myanmar, and Malaysia) joined the network in this follow-up phase. The Government of Indonesia continues to provide the Secretariat. The project still maintains the long-term objective of the previous phase, while emphasizing transfer of technology to the farmer, postharvest technology, socioeconomics, and under-exploited crops. The project emphasizes the need of ongoing intercountry cooperative activities for achieving successful results.

For training, a number of regional and national training courses and workshops have been organized, either by National Programs of the participating countries, or in collaboration with ICRISAT or CGPRT. Details of training (only those involving groundnuts) conducted so far are presented in Table 3. The projects encourage exchange of germplasm and information, although the incidence of peanut stripe virus in many member countries has hampered germplasm exchange.

Table 2. Training activities involving groundnuts sponsored by RAS/82/002 (1983–89).

Title	Venue	Date	Number of participants[1]
Short-term Training Courses			
Seed Technology for Coarse Grains and Food Legumes-I	UPLB[2], Laguna, Philippines	14 Apr to 14–16 May 1985	14
Seed Technology for Coarse Grains and Food Legumes-II	UPLB, Laguna, Philippines	14 Apr to 16–30 May 1986	16
Integrated Pest Management (IPM) of Legumes and Coarse Grains-I	SEAMEO-BIOTROP, Bogor, Indonesia	15 July to 9–20 Aug 1986	9
Rhizobium Technology and Inoculant Production	BNFRC, Bangkok, Thailand	2–27 Mar 1987	10
Detection of Groundnut Viruses with Special Emphasis on Peanut Stripe Virus	MARIF, Malang, Indonesia	11–26 July 1988	9+(3)
Seed Postharvest Handling for Coarse Grains and Food Legumes	UPLB, Laguna, Philippines	17 Oct to 17 Nov 1988	19+(13)
Disease Screening Techniques for Legumes and Coarse Grains	UPLB, Laguna, Philippines	21 Nov to 22 Dec 1988	19

Continued

Table 2. *Continued.*

Title	Venue	Date	Number of participants[1]
On-farm Research	CGPRT, Bogor, Indonesia	27 Nov to 10 Dec 1988	19
BNF Technology and Inoculant Production	BNFRC, Bangkok, Thailand	6–31 Mar 1989	18
IPM of Legumes and Coarse Grains-II	SEAMEO-BIOTROP, Bogor, Indonesia	15 May to 9 June 1989	17+(2)
Total			150+(18)
In-service Training			
Evaluation of Grain and Food Quality of Legumes	ICRISAT, Patancheru, India	1–14 Aug 1988	8
Integrated Control of Grain Legume Pests	ICRISAT, Patancheru, India	3–15 Oct 1988	4+(6)
Legume Pathology	ICRISAT, Patancheru, India	9–27 Jan 1988	2+(8)
Total			14+(14)
Workshop and Consultants' Meeting			
Workshop - I Towards Recommendations for Research, Policy, and Extension: Methodological Issues in Socio-economic Analysis of Legumes and Coarse Grains	Bandung, Indonesia	18–23 Nov 1988	24+(23)
Workshop - II Research Strategies for Improved Production of Food Legumes and Coarse Grains in the Tropics and Sub-tropics of Asia	Chiang Mai, Thailand	4–5 Aug 1988	64+(34)
Consultants' Meeting Use of Grain Legumes	ICRISAT, Patancheru, India	27–30 Mar 1989	5+(49)
Total			93+(106)
Study Tours			
Small Farm Machinery	Phitsanulok-Sukhothai, Thailand	25–28 Apr 1988	8
Research, Production and Marketing of Food Legumes and Coarse Grains	Northeastern Thailand	1–2 Oct 1988	10
New Development on Food Legumes and Coarse Grains	Central and East Java, Indonesia	29–31 May 1989	8+(1)
Total			26+(1)

1. Numbers in parentheses were not sponsored by RAS/82/002.
2. UPLB = University of the Philippines at Los Baños; SEAMEO-BIOTROP = Southeast Asian Minister of Education Organization-Regional Centre for Tropical Biology; BNFRC = Biological Nitrogen Fixation Research Centre; MARIF = Malang Research Institute for Food Crops; CGPRT = Centre for Regional Coordination of Research and Development of Coarse Grains, Pulses, Roots, and Tuber Crops in the Humid Tropics of Asia and the Pacific.

Source: FAO 1991b.

Table 3. Training activities involving groundnuts sponsored by RAS/89/040 (1990–91).

Title	Venue	Date	Number of participants[1]
Short-term Training Courses			
Seed Production of FLCG[1]	KU[2], Kamphaengsaem, Thailand	1–26 Oct 1990	14
Quality Evaluation and Utilization of FLCG	KU, Bangkok, Thailand	1–28 Oct 1990	14
Mechanism of Host Plant Resistance to Insect Pests in Legume Crops	ICRISAT, Patancheru, India	20 Feb to 5 Mar 1991	7
Groundnut Production (National)	Weihey, Shandong, China	15–24 May 1991	80
On-farm Research with Special Emphasis on On-farm Trials	MARIF, Malang, Indonesia	16–25 May 1991	26
Screening for Resistance against Diseases and Use of Biotechnology for Detection of Plant Pathogen	BORIF, Bogor, Indonesia	16–30 May 1991	17
Evaluation and Utilization of Germplasm of Legumes and Coarse Grains	UPLB, Laguna, Philippines	14–26 Oct 1991	28
In-service Training Course			
Minor Food Legumes (National)	INSA, Hanoi, Vietnam	8–15 Apr 1991	60
Workshops			
Postharvest Handling and Utilization of FLCG in Asia Emphasizing the Role of Small Scale Industries	MARDI, Kuala Lumpur, Malaysia	26–27 Apr 1991	40
Grain Legumes Production in Laos (National)	NARC, Naphoc, Vientiane, Laos	4–6 Nov 1991	–

1. Food Legumes and Coarse Grains.
2. KU = Kasetsart University; MARIF = Malang Research Institute for Food Crops; BORIF = Bogor Research Institute for Food Crops; UPLB = University of the Philippines at Los Baños; INSA = Vietnam Agricultural Science Institute; MARDI = Malaysian Agricultural Research and Development Institute; NARC = National Agricultural Research Center.

In addition to the activities conducted by the Secretariat of RAS/89/040 in cooperation with government institutions of the participating countries, FAO has made contract arrangements with two international centers in the region to conduct specific activities.

CGPRT Centre. A grant of US$ 200 000 has been given to the Economic and Social Commission for Asia and the Pacific's (ESCAP) CGPRT Centre in Bogor, Indonesia, to undertake socioeconomic studies on processing and marketing of FLCG crops to expand rural incomes and job opportunities in developing Asia. The objectives of this study are: 1) to expand the existing data base and to improve the awareness of crop diversity for agricultural development; 2) to manage and disseminate information useful to policy makers and scientists in developing countries of Asia for policy formulation and R&D relating to FLCG crops; and 3) to improve the capabilities of researchers and local extension workers to be able to adjust the national/provincial recommendation at the farm level and identify relevant farm problems to be solved. The study is currently in progress.

ICRISAT. Another grant of US$ 660 000 has been made to ICRISAT to carry out a 3-year project entitled "Testing and Adaptation of Technology for Increased and Stabilized Groundnut, Pigeonpea, and Chickpea Production in South and Southeast Asia". The objectives of this study are: 1) to assist NARS to assemble available information from research and extension sources within the project countries and the region that could be used in generating production technologies; 2) to generate and test crop production technology under research station and in farmers' fields; 3) to modify the most effective production technologies to suit real farm situations; and 4) to enhance the adaptive research capabilities and interest of NARS in legume production. The letter of agreement was signed on 30 April 1990 and the work is now in progress. One of the activities conducted by ICRISAT under this project was the organization of the Asian Grain Legumes On-farm Research (AGLOR) Planning Meeting in Malang, Indonesia, in which various techniques for site characterization through a rapid rural appraisal were discussed.

Proposed Future Activities

Groundnut is mainly a small-holder's crop upon which millions of people in tropical countries depend for their livelihood. Increases to groundnut production have largely been due to an increase in the area cultivated rather than from yield increases. There is a need to intensify crop production and increase productivity of groundnut. The goals of researchers should be to develop a sustainable cropping system that gives high yields and conserves the available natural resources. In an attempt to solve existing agronomic and socioeconomic problems, and from the lack of a technology transfer system, FAO, in collaboration with certain international agencies, is currently formulating two projects to be implemented in countries in Asia and Africa.

Sustainable Cultural Management Systems

At present, there still exist many agronomic problems that must be integrated into a practical system for groundnut producers. Improved cultural management practices would also reduce aflatoxin contamination. Many problems are specific to an agroecological zone and require investigation by staff of national programs with assistance from international programs. The latter need to develop principles and methodologies that can be transferred to national programs for solving location-specific problems. Thus, there is a need to continue the present research efforts at ICRISAT. Results from these studies could then be transferred to national programs for application.

Although ICRISAT has initiated small-scale on-farm adaptive research in four Asian countries, additional agronomic and socioeconomic studies are required on a regional basis on the problems encountered in land preparation, seed availability and quality, plant populations, fertility, water use, weed control, harvesting, intercropping, and use of appropriate small-scale equipment. This project would include provision for seminars to coordinate research activities and training extension workers.

Centre for Dissemination of Groundnut Information

A great deal of information on groundnut production, processing, and marketing has been established by research, but it often has little impact because of the lack of documentation and dissemination. The lack of rapid dissemination of up-to-date information, in appropriate formats and languages, among institutions involved in all aspects of the groundnut economy, including research and extension, is a serious constraint to the adoption of new techniques and policies. Furthermore, the failure to transfer information to farmers in appropriate language and format by national programs limits the usefulness of research, especially in developing countries.

Despite the existence of several networks that disseminate information to their members, there is a need to strengthen the world groundnut information service. ICRISAT, FAO, the Institut de recherches pour les huiles et oléagineaux (IRHO), the Commonwealth Agriculture Bureaux International (CABI), the Natural Resources Institute (NRI), and the Royal Tropical Institute (RTI) are among the institutions that collect, collate, and disseminate groundnut information. A central organization with facilities for automatic data processing and for compiling and distributing information would facilitate the free flow of information on groundnut research and thus expedite its application by providing information in appropriate languages for groundnut researchers, extension workers, farmers, and market operators through literature and workshops. Appropriate newsletters and high quality publications dealing with new methodologies and technologies are required to facilitate dissemination of research and utilization of results. There is also a need to provide assistance and services to national programs to translate and provide information to groundnut farmers. Handbooks detailing production practices, diseases, insect pests, appropriate technologies, and underlying market conditions are required by researchers, extension specialists, market operators, and farmers.

Conclusion

The role of FAO in groundnut research and production has been limited during the past decade as the result of the establishment of ICRISAT, one of the IARC's with groundnut in its mandate. FAO's role is to assist NARS in obtaining needed information, technology, and genetic materials, and in adaptive research to be applied in the local production environment. This has been carried out successfully in Africa and, to some extent, in Asia. In the latter, more emphasis has been given to the role of networking among member countries. Both projects RAS/82/002 and its successor, RAS/89/O40, are unique in several respects. They are structured to increase awareness among member countries on various aspects of crop production including socioeconomic needs. They rely on providing a forum for exchange of information, techniques, and materials. The mode of interaction chosen is to encourage technical cooperation among developing countries (TCDC) rather than to seek technical assistance from the developed world. Finally, the projects rely on these benefits offered by the formation of regional networks.

Although a number of international agencies are involved in groundnut research and production, many agronomic and socioeconomic problems specific to each region are yet to be solved. The lack of documentation and dissemination of research results is a bottleneck to the adoption of technology on small land holdings. At least two projects are being formulated by FAO in order to overcome these constraints.

Literature Consulted

FAO. 1990. 1989 Production Yearbook vol. 43. Rome, Italy: FAO

FAO. 1991a. Selected indicators of food and agriculture development in Asia-Pacific region, 1980–90. Bangkok, Thailand: FAO, Regional Office for Asia and the Pacific.

FAO. 1991b. Terminal report of FAO/UNDP project: the research and development of food legumes and coarse grains in the tropics and sub-tropics of Asia (RAS/82/002). Rome, Italy: FAO.

The Peanut Collaborative Research Support Program: Goals, Accomplishments, and Future

D.G. Cummins[1]

Abstract

*Groundnut (*Arachis hypogaea*) is a crop grown in most countries, both developing and developed, between latitudes 40°N and 40°S. The constraints to its production and use are similar worldwide, and there is potential for collaborative research to relieve these constraints. Groundnut can contribute usefully to food supply in areas where total food and protein is inadequate.*

It is becoming increasingly evident that agriculture must be sustainable. Groundnut contributes to sustainability because it can be productive while maintaining or enhancing the environment in the following ways.

- *It fixes atmospheric nitrogen through bacterial symbiosis, thus returning nitrogen to the soil for its own use and for use by future crops.*
- *It provides a nearly closed canopy that minimizes soil erosion.*
- *Its relatively short growing season makes it fit within a range of cropping systems, both monoculture and multi-cropping, as well as intercropping with grain crops and under-storey sowing in tree crops. It can be sown late in the season when previous crops have been lost or were poor producers.*

Other advantages of groundnut are:

- *It is an important source of high protein and energy for humans, as well as a high-quality animal feed.*
- *It provides a source of cash income for rural and urban people.*
- *It adds to supplies of vegetable oil.*
- *It tolerates drought conditions, including the extreme drought of sub-Sahelian Africa. Groundnut is also able to mature in the short rainy season of that area.*
- *It suppresses weeds when intercropped with grain crops and reduces labor-intensive weeding.*

Résumé

***Le programme américain d'appui à la recherche collaborative sur l'arachide—objectif, réalisation et avenir:** L'arachide (*Arachis hypogaea*) est une culture qui se pratique dans la plupart des pays en développement ou développés, entre les latitudes 40° N et 40°S. Les contraintes de sa production et de son usage sont analogues dans le monde entier et la recherche en collaboration permettra de les lever. L'arachide peut contribuer utilement à accroître les ressources alimentaires dans des régions qui sont carencées en aliments et notamment en protéines.*

1. Program Director, Peanut Collaborative Research Support Program, Georgia Experiment Station, University of Georgia, 528 Ivy Road, Griffin, GA 30223-1797, USA.

This publication was made possible through support provided by the Office of Agriculture, Bureau of Research and Development, U.S. Agency for International Development, under Grant No. DAN 4048-G-00-0041-00.

Cummins, D.G. 1992. The Peanut Collaborative Research Support Program: goals, accomplishments, and future. Pages 187–192 *in* Groundnut – a global perspective: proceedings of an international workshop, 25–29 Nov 1991, ICRISAT Center, India (Nigam, S.N., ed.). Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Il est de plus en plus évident que l'agriculture doit être reproductible. L'arachide contribue à cette durabilité, parce qu'elle peut produire tout en conservant ou en enrichissant l'environnement par les procédés suivants:

- *Elle fixe l'azote atmosphérique par une symbiose bactérienne, rendant ainsi de l'azote au sol pour son propre usage et celui de cultures ultérieures.*
- *Elle fournit une couverture végétale dense qui réduit au minimum l'érosion du sol.*
- *Son cycle relativement court lui permet d'intégrer dans toute une gamme de systèmes de culture, monoculture ou polyculture, ainsi qu'en culture associée avec des céréales et par des semis sous des cultures agro-forestières. Elle peut être semée tard dans la campagne, lorsque des cultures précédentes ont été perdues ou ont eu de mauvais rendements.*

Voici d'autres avantages de l'arachide:

- *C'est une source importante de protéines riches et d'énergie pour les êtres humains, ainsi que d'affouragement animal de haute qualité.*
- *Elle fournit une source de revenus monétaires aux ruraux et urbains.*
- *Elle augmente les réserves d'huile végétale.*
- *Elle tolère la sécheresse, y compris la sécheresse extrême en Afrique sud-sahélienne. L'arachide peut également parvenir à maturité pendant la saison des pluies très courte de cette région.*
- *Elle étouffe les mauvaises herbes lorsqu'elle est cultivée en association avec des céréales et elle réduit le désherbage qui exige beaucoup de main d'oeuvre.*

The Peanut Collaborative Research Support Program (CRSP) was implemented in 1982. The CRSPs were created to implement the Title XII program of the United States Foreign Assistance Act of 1975 with a goal to prevent famine and establish freedom from hunger through land-grant university involvement in international development. To attain the goals, the research capability of a developing country and U.S. institutions is enhanced through training and support of research. Inherent in the CRSP concept is the need to address constraints that have global implications. Therefore, the enhanced research capability is focused on the alleviation of major researchable constraints that limit sustainable production and food delivery through an environmentally sound system.

The Peanut CRSP is funded by the United States Agency for International Development (USAID) through Grant Number Dan 4048-GG-00-0041-00. In addition the participating U.S. and host country institutions share costs in support of the program.

Constraint Driven

The Peanut CRSP was designed around a set of constraints to sustainable production and utilization identified during the 1980–82 planning process. Based on the numerous advancements achieved by the Peanut CRSP during the 1982–89 period, the External Evaluation Panel in 1989 evaluated the continuing validity of the following constraints and found them to be valid as a basic framework for the Peanut CRSP for the near future:

- Low yields resulting from unadapted cultivars and lack of cultivar resistance to diseases, insects, and drought;
- Yield losses due to infestations of weeds, insects, diseases, and nematodes;
- Health hazards and economic losses due to mycotoxin contamination;
- Inadequate food supplies and lack of appropriate food technologies to exploit a relatively well-adapted groundnut crop that is not generally considered a primary food source;
- Physiological and soil microbiological barriers to higher yields;
- Resource management (agronomic, engineering, economic, and sociological) situations preventing efficient production and utilization;
- Inadequate numbers of trained researchers and support personnel;
- Lack of adequate equipment to conduct research; and
- Information not available to beneficiaries for support of production and utilization efforts.

In short, the Peanut CRSP enhances the potential of groundnut as a crop for human food and animal feed in developing countries and the United States, as it contributes to the increase of rural incomes and sustains agricultural land. The collaborative research on groundnut is producing new and improved technology that increases the well-being of people in developing countries and, in turn, benefits citizens in the USA.

The Global Plan

Groundnut has a global nature resulting from its worldwide distribution, its importance in both developing and developed countries, and for the marked similarity of production and utilization constraints worldwide. There is also potential for research to relieve production and utilization constraints and better realize this potential to contribute to an increased food supply in countries where total food and protein supply is marginal. Finally, there is a synergistic effect of cooperation among international agricultural research centers and other donor groups.

Global thrusts

Sustainability of production and delivery of food to the human population is a primary problem in the developing world. Based on the importance of groundnut in contributing to sustainable production of food, and the need to optimize crop production, the Peanut CRSP has three global thrusts to relieve the problem:

1. Conduct of environmentally sound research to relieve the identified constraints to production and utilization;
2. Location of resource management systems to relieve situations that restrict efficient management of production and utilization; and
3. Communication of research outputs to clientele.

An integral part of the research activity is an enhancement of research capability for both the USA and the host countries through collaborative research, the provision of equipment, and the training of research and support personnel.

Since its inception, the Peanut CRSP has enhanced research and technology transfer activities through synergistic relationships with other international organizations. Cooperative planning, support for research, and conduct of workshops and other outreach activities characterize these global relationships. Organizations include the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), the ICRISAT Sahelian Center (ISC), the Institut de recherches pour les huiles et oléagineaux (IRHO), the Conference des Responsables Africains et Francais de la Recherche Agronomique (CORAF), Canada's International Development Research Centre (IDRC), and the Australian Centre tor International Agricultural Research (ACIAR). The External Evaluation Panel and the Administrative Review Team both recognized the benefits of cooperation with these organizations.

Paramount to our goals is the provision of information of value to beneficiaries. The collaborative nature of the CRSP results in two-way benefits with:

- Focus on solving constraints and improving the well-being of people in host countries; and
- Results of value to the constituents of the participating U.S. institutions.

Host country beneficiaries are small-scale farmers, which include rural women, as well as food processors and rural and urban consumers. Benefits come in the form of adequate quantities of more nutritious and safe food, and increased incomes to growers.

United States beneficiaries are farmers, processors, and rural and urban consumers.

The Peanut CRSP Global Plan is a framework for the implementation of the program, and is a template against which progress toward reaching goals can be measured. Research is a dynamic process, not an event; consequently, Peanut CRSP management will revisit the Global Plan on a continuing basis to keep CRSP abreast of changes in the international groundnut research environment while keeping in mind the contribution of advancements in research and maturation of technologies for transfer to beneficiaries on the continued development of the program.

Collaboration

The Peanut CRSP research programs are conducted collaboratively between scientists in host country and U.S. institutions. Constraints are addressed in the research that solves problems with the host country, while at the same time having regional and global implications. The research also has return benefits to the USA.

The program is collaborative between four U.S. universities and institutions in four regions: West Africa, Southeast Asia, the Caribbean, and the Near

East. The Near East program was added with USAID Mission support in 1991, while the program has been active in the other three regions since 1982. The following institutions and countries are active in the Peanut CRSP:

USA

Alabama A&M University
University of Georgia
North Carolina State University
Texas A&M University

West Africa

Institut sénégalais de recherches agricoles (ISRA), Senegal
Institut sénégalais de technologie alimentaire (ITA), Senegal
Institut supérior polytechnique (ISP), University of Ouagadougou, Burkina Faso
Institut national de recherches agronomiques du Niger (INRAN), Niger
Institute of Agricultural Research, Ahmadu Bello University, Nigeria
Institut d'économie rurale (IER), Mali

Southeast Asia

Philippine Council for Agriculture, Forestry and Natural Resources Research and Development (PCARRD), Los Baños, Philippines
Institute of Plant Breeding, National Crop Protection Center, Institute of Biotechnology, and the University of the Philippines, Los Baños, Philippines
Thailand Department of Agriculture, Kasetsart University, and Khon Kaen University, Thailand

Caribbean

Caribbean Agricultural Research and Development Institute (CARDI), Headquarters on the University of West Indies' Campus, St. Augustine, Trinidad

Near East

Agricultural Research Centre, Dhoki, Cairo, Egypt

The University of Georgia is the Management Entity for the Peanut CRSP; it receives the Grant from USAID and subgrants to the four U.S. institutions that establish collaborative arrangements with the host country institutions.

The long-term collaborative relationships inherent in the Peanut CRSP provide a basis for strengthening the research capability of both the U.S. and host country institutions to focus on solutions to problems constraining groundnut production and utilization.

Results of the Program

Research projects of the Peanut CRSP fall into four major categories to match the constraints: genetic resources for groundnut cultivar development and adaptation; integrated pest management; natural resource management; and food products and consumer use. In addition, human resource and institutional development and communication and outreach are important components of the Peanut CRSP.

Genetic resources

The Peanut CRSP has accessed the world collection of groundnut germplasm and used it to develop, through both conventional and advanced biotechnological techniques, genetic lines with superior attributes. These superior lines were used to develop and release at least 15 new cultivars. These new cultivars have higher yield potential, increased tolerance to diseases and insects, and better quality and consumer acceptability. Development of other cultivars with tolerance to drought and aflatoxin is ongoing.

Genetic lines and cultivars developed or selected have shown termite resistance in Burkina Faso, rosette virus resistance in Nigeria, black rot resistance in North Carolina, and provided higher yields in Thailand, the Philippines, Jamaica, and Texas. Interspecific hybrids between cultivated and wild species and gene transfer through biotechnological techniques re being used to increase stress tolerance in cultivated groundnut species.

Integrated pest management

Peanut CRSP researchers have determined insect life cycles, alternate plant hosts, time of appearance of insects on the crop, insect population levels, and subsequent damage to the plant. Such knowledge provides the basis for IPM recommendations and programs that contribute to lower use of chemicals. Research is ongoing in genetic control through resistant cultivars, cultural control, biological control (fungal, bacterial, and parasitic insects), and naturally occurring chemicals. Improved IPM programs promise to provide economic and safety benefits to farmers and to lessen the potential harmful effects of chemicals on the environment. Breeding programs can use groundnut lines selected for their increased tolerance to insects to develop insect-resistant cultivars. Development of pest-resistant cultivars and cultural and biological controls have already helped guide IPM strategies to decrease the use of chemical pesticides.

Insect-tolerant lines have been identified in Burkina Faso, the Philippines, Thailand, and the USA, and these can be used in development of insect-tolerant cultivars. The use of biological control agents has been enhanced in Burkina Faso and the Philippines. Control of termite damage in Burkina Faso lowers aflatoxin contamination in groundnut. A potential peanut stripe virus epidemic was thwarted in the USA, avoiding extensive yield losses. IPM research has established thresholds for economic damage from insects to minimize the use of chemical pest control with savings in cost of chemicals and application in North Carolina, Virginia, and the Philippines. Additional benefits come from lowered use of chemicals that may damage the environment. Work continues to improve the control of rosette and tomato spotted wilt viruses, improve the use of biological control agents, select insect-tolerant germplasm, and develop and refine IPM technologies.

Natural resource management

Effective use of natural resources enables efficient production of groundnut. Agronomic, economic, engineering, and sociological means are used to improve the use of the resources. Agronomically, cropping practices must ensure that production is sustainable and is not detrimental to the environment. Labor-saving mechanical devices need to be introduced where feasible. New technology must fit into the sociological framework of the society. Above all, the total system must be economical.

In the Philippines a production survey helped determine the direction of research to relieve present constraints. In Burkina Faso and Thailand soil resource analyses of research sites assisted in transfer of information to production areas. In the Caribbean, the Philippines, Thailand, and West Africa food consumption surveys assisted in development and improvement of food products directed to fit local tastes, consumption patterns, and expressed needs for new processes or products. In West Africa, a socioeconomic study identified constraints to production and use of groundnut. An impact study in Jamaica showed a 42% yield increase in farm production fields by the CRSP-released CARDI-Payne cultivar compared to the traditionally used cultivar, with 10% of the farmers adopting the new cultivar in 2 years. Low soil pH and high soil aluminium content appear to lower yields in southwestern Burkina Faso.

Food products and consumer use

The Peanut CRSP seeks to harvest, store, and process groundnut in ways that will supply adequate quantities of safe and acceptable products to consumers. A major objective is to minimize and detoxify aflatoxin, a highly carcinogenic metabolic product of *Aspergillus flavus*, in food products. Other objectives are to increase awareness of the high energy and protein value of groundnut; to increase the use of groundnut in traditional foods; and to develop new products that are culturally acceptable.

Research in Senegal and Texas has shown that a highly sorbent clay can remove aflatoxin from crude groundnut oil; the clay added to poultry feed binds the aflatoxin and prevents it from accumulating in poultry livers, and when added to goat rations eliminates aflatoxin from milk. In Burkina Faso, IPM practices to reduce termite damage to pods prior to harvest reduced *Aspergillus flavus* entry and aflatoxin accumulation in the seed. In West Africa, products made from cereal grain flours have been enriched with groundnut flour. In the Philippines, a groundnut-based cheese-flavored spread has been accepted by consumers. In Thailand, groundnut flour-enriched wheat (*Triticum aestivum*) noodles were highly acceptable to consumers. The nutritive value of popular extruded snacks in Thailand is being improved by the addition of groundnut flour. Curd and yogurt products are being developed using groundnut milk in the Philippines. Acceptable coffee or tea whitener has been developed in the USA.

Human resource and institutional development

Training is an integral part of all research, both to upgrade the skills of present researchers and to provide graduate training to develop researchers to fill present and future voids. To attain the goals of the Peanut CRSP, the research capacities of developing countries and U.S. institutions are enhanced through training and research activities. In a recent review of the program, the External Evaluation Panel stated that "the training of young agricultural scientists, or the stockpiling of human capital, will probably be the longest lasting and most cost-effective accomplishment of the Peanut CRSP."

The Peanut CRSP has provided funds and training for over 50 M.S. and Ph.D. students from the host countries; over 30 M.S. and Ph.D. students from non-host countries; and over 40 M.S. and Ph.D. students from the USA. Over 30 students have been trained at the M.S. level and one at the Ph.D. level in host country institutions. Over 200 man-months of short-term training at U.S. universities were provided to over 75 developing country scientists. U.S. scientists provided over 80 man-months of technical assistance in the host countries.

Research capabilities in both the host countries and the United States were enhanced through the provision of funds for labor, supplies, and equipment.

Communication and outreach

Paramount in the goals of the Peanut CRSP is providing information of value to beneficiaries. Efforts in communication and outreach help extend new technology and provide feedback on consumer and producer needs. Technology use has been stimulated by numerous publications, workshops and conferences, annual in-country planning sessions, and on-farm pilot programs.

About 200 scientific journal articles, 9 book chapters, some 200 miscellaneous articles, and over 200 abstracts were published, providing information on results. The *International Arachis Newsletter* is published in cooperation with ICRISAT.

Over 35 workshops and conferences were sponsored or cosponsored. Annual meetings were developed and continue in the Philippines and Thailand.

On-farm cultivar and IPM pilot programs were developed in the Philippines and Jamaica. New food products have been market and consumer tested in the Philippines and Thailand.

Benefits and Impacts

The collaborative nature of the CRSP results in two-way benefits, with resolution of constraints to production and use that improves the well-being of people in developing countries and provides results of value to constituents of U.S. universities. Benefits come in the form of adequate quantities of more nutritious and safe food and in the increased well-being of farmers, food processors, and rural and urban consumers.

Future Plans

The Peanut CRSP is presently authorized for funding through 30 June 1995. During 1992–94 a review and planning process will be undertaken with the view of a 5-year extension beginning 1 July 1995.

Annual reviews and planning efforts continually modify the program to keep it abreast with current problems. Major reviews may change program directions and could cause changes in institutions and countries participating in the CRSP. Expansions to new countries may result from support from local USAID missions or other sources, such as the recent addition of Egypt to the program.

Sustainable production and food delivery systems have been a focus and will continue to be strengthened in the Peanut CRSP. These sustainable systems must be environmentally and economically sound.

The Contributions of ACIAR to Groundnut Research

K.J. Middleton[1]

Abstract

*The Australian Centre for International Agricultural Research (ACIAR) has been in existence for almost 10 years, and in that time has established a good reputation for supporting research into agricultural problems in tropical areas, particularly in subjects in which Australian scientists have some competitive advantage. Groundnut (*Arachis hypogaea*) problems have been investigated chiefly through an ACIAR-funded project collaboratively conducted by the Indonesian Agency for Agricultural Research and Development, and the Queensland Department of Primary Industries, Australia. This project has operated for over 6 years, and will terminate in 1992. During this time the project has investigated groundnut diseases, genetic and managerial resolution of drought, and environmental constraints, such as photoperiod, irradiance, and nutritional deficiencies. As a result further new projects aimed at finding specific solutions to clearly defined problems have been formulated. Several other projects with a broader scope have included groundnuts among the crops investigated.*

Résumé

Les contributions de l'ACIAR à la recherche arachidière: *Le Centre australien pour le recherche agricole internationale (ACIAR) existe depuis près de 10 ans et pendant cette période, il s'est assuré une bonne réputation en appuyant la recherche sur des problèmes agricoles dans les zones tropicales, particulièrement sur des sujets à l'égard desquels les scientifiques australiens ont un certain avantage compétitif. Les problèmes de l'arachide (*Arachis hypogaea*) ont été étudiés surtout grâce à un projet financé par l'ACIAR et conduit en collaboration par l'Agence indonésienne de recherche et de développement agricoles et le Ministère des industries primaires du Queensland. Ce projet fonctionne depuis plus de six ans et prendra fin en 1992. Pendant cette période, dans le cadre de ce projet ont été étudiés, les maladies de l'arachide, la lutte au niveau génétique et de la gestion contre la sécheresse et les contraintes de l'environnement, comme la photopériode, l'irradiation et les déficiences nutritives. En conséquence, de nouveaux projets visant à trouver des solutions spécifiques pour des problèmes clairement définis ont été formulés. Plusieurs autres projets à vaste portée ont inclus l'arachide parmi les cultures étudiées.*

The Australian Centre for International Agricultural Research (ACIAR) promotes research into improving agricultural production in developing countries. It mobilizes Australian agricultural research expertise to help developing countries to help themselves. Its collaborative research programs help partner countries to identify and solve their major agricultural problems, and at the same time to strengthen their research capacity.

This independent statutory authority was established in June 1982 by an Act of the Australian Parliament. Its activities are part of Australia's overseas

1. Formerly Principal Plant Pathologist, Queensland Department of Primary Industries, J. Bjelke-Peterson Research Station, P.O. Box 23, Kingaroy, Queensland 4610, Australia.

Middleton, K.J. 1992. The contributions of ACIAR to groundnut research. Pages 193–204 *in* Groundnut – a global perspective: proceedings of an international workshop, 25–29 Nov 1991, ICRISAT Center, India (Nigam, S.N., ed.). Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

development assistance program, and it is responsible to the Minister for Foreign Affairs.

ACIAR contracts research groups in institutions in Australia to collaborate with their counterparts in developing countries to study high priority developing-country problems in fields in which Australia has particular scientific and technical competence.

For ACIAR, agriculture is broadly defined to include animal and crop production, land use, and related fields such as forestry, economics, and postharvest technology.

ACIAR's mandate in identifying agricultural problems and supporting research to help solve these problems focuses on fields in which Australia has a special research competence. Because of its ecological similarities with many developing countries – a semi-arid environment, generally infertile soils, and a large proportion of land in the tropics – Australia has developed considerable expertise in solving problems related to these difficulties. This expertize has been mobilized and expanded for the benefit of developing countries.

Where ACIAR operates

ACIAR concentrates primarily on Southeast Asia, especially the countries of the Association of Southeast Asian Nations (ASEAN), Papua New Guinea, and the South Pacific. A limited proportion of its projects also focus on the People's Republic of China, and on the countries of South Asia and Africa south of the Sahara. Projects in West Asia and North Africa can only be considered in very special circumstances. ACIAR does not fund projects in South America, Central America, or the Caribbean region.

The researchers

The Centre does not normally carry out research itself; instead, it acts as a scientific broker to select research partners on the basis of their skills and willingness to undertake research on mutual problems. These partners come from Australian research organizations such as the Commonwealth Scientific and Industrial Research Organisation (CSIRO), state departments of agriculture and universities, and their developing country counterparts. Where appropriate, links may also be developed with the International Research Centers of the Consultative Group on International Agricultural Research (CGIAR), such as ICRISAT, to assist this direct collaboration.

ACIAR provides funds for approved research projects. It does not normally fund core support for institutions. It provides opportunities for training of nationals from developing countries within the context of approved collaborative research projects.

Priority program areas

ACIAR projects are developed within priority program areas, which reflect the fields of agricultural research needed by developing countries and in which Australia can offer special competence. The areas are:

- **Crop sciences:** plant improvement and plant protection topics, such as biological constraints to yield; physiology of tolerance to adverse conditions; technology to support selection and breeding programs; use of cytogenetic and genetic engineering techniques; support for improvement of less known, but important, crops (root, tree, and fruit crops); diagnosis and etiology of crop pests and diseases; breeding for disease resistance; pathogen detection; integrated pest management strategies; weed control; genetic basis of resistance; and biological control.
- **Plant nutrition:** topics such as biological nitrogen fixation; diagnosis and correction of nutrient and micronutrient deficiencies; and efficient management of nitrogen, phosphorus, and sulfur fertilizer.
- **Animal sciences:** animal production and animal health areas.
- **Soil and water management and land use:** soil constraints to food production; acid and nutrient deficient soils; efficient use of water in rainfed systems; land-use planning; and agroclimatology.
- **Forages:** forages in plantation crops; forage shrub production from saline and/or sodic soils; shrub legumes in the tropics; and forages on red soils.
- **Economics and farming systems:** social and economic aspects of increasing farm production and improving rural welfare; agricultural policy; commodity and market analysis; technology assessment; cost benefit and risk analysis; determining agricultural research policies; research on the components of the whole farm system and their interaction with the farm environment; agroecological zoning; modeling of existing farming systems and prospective technologies; farm surveys and analysis; and design of crop-forage-livestock systems improvement.

- **Postharvest technology:** safe storage of grain; technology to improve quality; and storage and transport of soft fruit and vegetables.
- **Forestry:** use of fast-growing hardwoods for fuelwood and agroforestry; silviculture of tropical softwoods; and wood utilization and preservation.
- **Fisheries:** coastal and marine stock assessment; aquaculture (including mariculture); and diagnosis and control of fish and shellfish diseases.
- **Communication:** primarily communication of ACIAR research results through scientific publications and in forms suitable for non-specialists; publicity; support for scientific journals; and studies of effective ways of disseminating results of ACIAR-supported research in partner countries.

While ACIAR prefers project topics within these broad program areas, its approach is flexible. Project proposals not within these areas will be considered on their merits.

Funding

Within projects, funding will be provided for:

- Direct research costs, including research assistance for the Australian institution and, where necessary, for its developing-country partners;
- Costs of exchanging staff between participating institutions, including provision of on-the-job training of developing-country nationals at the Australian institution; and
- Obtaining access to supplies, materials, and the maintenance needed specifically for the project.

In addition, if a preliminary proposal is judged suitable for further development, funding can be provided to ensure that developing-country partners participate fully in the preparation of final proposals for consideration by the ACIAR Board of Management.

The Director and staff are responsible for day-to-day management of the Centre, including preparation of research project proposals, administration of projects, and provision of administrative support.

ACIAR's support for groundnut research

A number of ACIAR projects have addressed problems associated with production or utilization of groundnut. By far the largest of these (in terms of time and manpower) is the project for Groundnut Improvement in Indonesia. Other projects which have addressed specific problems of groundnut include preliminary studies on bacterial wilt (*Pseudomonas solanacearum*) in Southeast Asia, biological nitrogen fixation, boron and other micronutrients in legume production systems, and fungi and mycotoxins in Asian food and feedstuffs. Other projects addressing serious problems with groundnut production have been proposed to the Board of Management of ACIAR.

Groundnut Improvement in Indonesia

This project has recently completed its second 3-year phase. The reviewers recommended that it should be terminated on 30 June 1992, that ACIAR support a project proposed for the production of transgenic groundnut plants with coat-protein mediated resistance to peanut stripe virus, and that another proposal for a project on water use efficiency in food legumes be considered.

This project covers a broad range of production constraints as shown by the following major objectives which are designed to:

1. Minimize losses due to bacterial wilt and peanut stripe virus;
2. Identify genotypic variation as a basis for improving drought resistance in breeding material; and
3. Explore environmental constraints that limit productivity of groundnuts, including photoperiod, low irradiance, and aspects of fertility including low pH, high aluminium saturation, and mineral deficiencies.

Management objectives addressed included:

4. Evaluation of strategies for controlling fungal pathogens of foliage with fungicides;
5. Testing plant population responses under irrigation;
6. Determination of appropriate water management strategies for lowland groundnuts grown after rice; and
7. Assessing the efficiency of biological N-fixation as a source of nitrogen for groundnuts in various cropping systems.

In addition, the project was to further develop a dynamic simulation model to enable prediction of cultivar adaptation, and to assist in definition of key breeding objectives.

The following abstracts indicate the degree of success achieved by the project scientists in meeting these objectives.

Genetic and Cultural Control of Bacterial Wilt

Bacterial wilt, caused by *Pseudomonas solanacearum*, is a major constraint to groundnut production in Indonesia. In an effort to improve groundnut production by reducing yield lost to this disease, research has addressed the following subjects:

1. Field surveys and collection of diseased plants have shown that bacterial wilt is still wide spread in Indonesia and a potential danger to groundnut production.
2. Identification of strains, biovars, and host range of the pathogen has shown that this organism can attack several species of weeds that are common in groundnut areas, and that most isolates collected from groundnut fields were of race 1, biovar 3.
3. An examination of the variation in virulence among isolates if the pathogen revealed a wide range in this trait, based on the wilt intensities on the cultivar Kelinci.
4. Methods of inoculation (suitable for screening germplasm) and transmission of this pathogen revealed that seed transmission at rates from 5% to 8% were possible.
5. Screening germplasm from a variety of sources for resistance to this disease detected several resistant lines which may be suitable either as sources of resistance in a breeding program, or for direct use as varieties to be made available to farmers.
6. Studies of the effects of crop rotation, soil type, and organic matter amendments on wilt intensity showed the value of rotation, particularly with paddy rice, in reducing incidence of wilt. Promising results from the use of animal manures invite questions about the mechanism whereby these treatments alter disease level. Bacterial wilt intensity was influenced by soil type.

The Influence of Some Environmental Factors and Isolate Variability on the Development of Groundnut Bacterial Wilt Caused by *P. solanacearum*

Bacterial wilt in groundnut is a serious disease in Indonesia, China, and Uganda although present in most countries. The reasons for this distribution have not been clear, and raise the possibility that the disease could become serious in other countries, should production practices or climate change. In parallel with the host resistance, host range and management studies being supported in Indonesia, the role of environment and pathogen variability in determining the impact of this disease have been the subject of postgraduate studies in Australia. These studies indicate that a specialized form of *P. solanacearum* is not required to cause this disease, but rather environmental conditions are a prime controlling factor. However, continued exposure of the pathogen population to groundnut, under conditions conducive to infection, may lead to the development of a form of the organism better adapted to infect the crop.

The Importance and Genetic Control of Peanut Stripe Virus

Peanut stripe virus (PStV) is considered to be the most important and widespread virus disease of groundnuts in Indonesia. Yield loss assessments at the Muneng and Jambegede experimental farms of the Malang Research Institute for Food Crops (MARIF) and the Bontobili experimental farm of the Maros Research Institute for Food Crops (MORIF) in 1988–1990 showed that yield losses were up to 50–60%. Plants affected in the seedling and flowering stages were more susceptible than older plants.

A search for sources of resistance was made by evaluating more than 10 000 germplasm entries from ICRISAT at Muneng and Maros. Unfortunately, all entries were susceptible to PStV infection, although a wild species (*Arachis duranensis*) was resistant to virus infection.

The seed transmission rate, which varied from 0.25 to 3.62%, was influenced by variety and the time at which the plants became infected. Attempts to seek varieties with tolerance or low seed transmission continue. A new project to address the PStV problem has also been approved recently.

Investigation of Drought-tolerance Traits Conferring Adaptation to Drought Stress in Groundnut

Increases in pod yields under water-limited conditions are possible through identification and selection of cultivars that are better able to resist and/or adapt to drought stress. This project involved detailed studies on physiological adaptations enabling superior performance of cultivars in response to drought stress, in order to identify reliable indices of drought resistance/tolerance. Selection for such traits should complement the existing breeding program in Indonesia and lead to more efficient use of time and resources.

Significant variation in cultivar ability to extract soil water from deep in the profile during severe droughts was demonstrated. Preliminary attempts were made to correlate root parameters measured in small pots with observed field-water extraction. The results indicated that significant variation in many root characters exists; however, further research is needed to identify simple screening techniques for deep water-extraction capability.

Significant variation in transpiration efficiency (TE) under water non-limiting and water-limited conditions was shown among groundnut cultivars grown in the glasshouse and in small canopies in the field. There is considerable scope for TE improvement in Indonesia. TE was shown to be highly correlated with carbon isotope discrimination (Δ), and also specific leaf area (SLA), or leaf thickness. Selection for Δ or SLA provides a simple, non-destructive method for screening of high TE in groundnut.

Significant cultivar variation in partitioning of dry matter to pods, or harvest index (HI), was demonstrated. This trait was shown to be very important in determining pod yield variation among cultivars grown under drought conditions in Indonesia. Harvest index is easily measured, and preliminary genetic studies indicate heritability is high.

A negative association between TE and HI among the groundnut cultivars studied was apparent. Preliminary genetic studies aimed at assessing whether the association was due to a genetic linkage indicated that the negative association existed up to the F_4 generation in a cross of two contrasting Indonesian groundnut cultivars. Further research aimed at identifying cultivars with high levels of TE and HI is warranted. Breeders will need to be aware of the potential negative association in a breeding program incorporating TE (via Δ or SLA) as a selection trait.

Effect of Photoperiod, Temperature, and Irradiance on Groundnut Growth and Development

Limits to production imposed by environmental components such as temperature, photoperiod, and irradiance were examined intensively in this project. Research was undertaken in both field and controlled environments, with significant achievements including:

1. Identification of photoperiod–temperature interactions that explained the phenomenon of short-day cultivars able to produce good yields and high HI under long-day, subtropical conditions. This result questions the need for extensive screening of germplasm (particularly of foliar diseases resistant lines) for photoperiod sensitivity.
2. Demonstration of the role of minimum temperature in determining rates of dry-matter accumulation in subtropical environments, and highlighting the potential advantages in identification of cool tolerant lines.
3. Quantifying the relationship between specific leaf nitrogen and radiation use efficiency at a range of night temperatures, and showing the lack of evidence of significant nitrogen limitations to dry matter accumulation during pod-fill under well-watered conditions.
4. Demonstrating the effects of low levels of irradiance on HI in groundnut, and identification of varying levels of cultivar sensitivity to low irradiance both among and within botanical types. Evidence of possible temperature-irradiance interactions in HI determination require further study, and probably hold the key to improving crop yield potential in many Indonesian environments.

Much of the follow-up work in this area (with the exception of studies of nitrogen nutrition under stress conditions in the field) will generally require controlled environment facilities. However, potential benefits of such follow-up work will be large for Indonesian and Australian groundnut production.

Investigations into Lime Requirements for Groundnut, and Screening of Germplasm for Tolerance to Acid Soils

The effects of soil acidity on groundnut production have been examined on red-yellow podsolic soils at Sitiung, West Sumatra. Research has included:

1. A study of effects of rates of applied dolomitic limestone on soil chemical characteristics and groundnut growth;
2. Investigations of the residual value of that limestone, in interaction with effects of organic residue management; and

3. Establishment of an acid-soil nursery for selecting cultivars tolerant to varying levels of soil acidity.

Research has shown that:

- High levels of groundnut production can be achieved with amelioration of acid soil to overcome problems of aluminium and manganese toxicities, and possibly calcium deficiency.
- The residual value of applied limestone is significant, but declines rapidly unless other agronomic inputs are included in the management package (for example, incorporation of crop residues or other organic matter).
- Significant genotypic variation exists for performance under various levels of soil acidity, with some of the cultivars showing high levels of tolerance compared to local checks. However, aspects of overall seed quality/plant establishment and management options for the most acid nursery area (that is, unlimed soil) need to be addressed.
- While production advantages can be achieved by cultivar selection, these can only be maintained by integration with a soil management package that will halt further increases in soil acidity with cropping.

A number of areas of future research priority that have been identified, and that should be part of any future groundnut research program in Indonesia include:

- An effective determination of the relative importance of aluminium and manganese (and other ?) nutrition in groundnut yield limitation at the various levels of soil acidity;
- Determination of an effective, low input agronomic management package that will halt increasing levels of soil acidity under cropping; and
- Establishment of better linkages to other international projects also involved in acid soil work – especially with groundnuts.

Investigations into the Role of Macronutrient Deficiencies in Limiting Groundnut Yields in Java

Agronomic studies in East, Central, and West Java have highlighted major problems with adoption of a national fertilizer recommendation (N, P, and K) for groundnuts in Indonesia. Responses to N fertilizer have been limited, or nonexistent, and the responses to P and K applications have varied widely with location. Clearly, optimizing fertilizer-use efficiency by low-input, small farmers is an area for future research.

Studies in Central Java have highlighted the necessity of determining primary nutritional limits to crop productivity to maximize fertilizer-use efficiency. Many of the fields in the Jakenan area show severe K deficiency, with effects of P deficiency also apparent but less widespread. Soil analytical procedures need to be improved so that yield:soil test relationships can be developed for groundnuts in this area. Results to date have begun to establish the yield:soil test data base for K, but considerable input in this area is needed. Once that has been completed, follow-up work on rates and methods of K (and P) fertilizer applications should follow.

The widespread 'yellow symptom' of groundnut in Tuban district and neighboring areas of East Java has been shown not to be due to K deficiency as previously thought. Rather, soil and plant analytical data suggest a pH-induced micronutrient deficiency (probably zinc) that cannot be completely overcome by foliar trace element applications. Severe yield restrictions due to this deficiency are evident, and extensive inputs are needed to both conclusively identify the deficiency and also to develop appropriate agronomic methods of overcoming it. This will require a significant analytical input (both soil and plant) which appears to be unavailable in currently used laboratories.

A requirement for fertilizer N has only been demonstrated in one study in Indonesia during this project. We have been unable to repeat that result and are currently awaiting data to determine relative contributions of biologically-fixed N and mineral N to the total N economy of the groundnut crop in a trial in West Java. The relative ease of collection of root bleeding sap from groundnut under Indonesian field conditions should mean this technique may be used more widely to gather information on this aspect of groundnut production.

Management of Groundnut Foliar Diseases

While host resistance to the foliar diseases is an admirable goal of a groundnut improvement program, it remains a reality that crops in many countries are still being damaged. As an interim measure, consideration must be given to the use of fungicides to optimize farmers' returns from these crops. However, in some situations the use of fungicides will result in increases in crop value less than the cost of controlling the disease (the cost of fungicide plus cost of application). It therefore becomes important to formulate some method for deciding whether the use of fungicide is economically justifiable.

Important considerations in reaching that decision include a knowledge of the biological spectrum of candidate fungicides, their mode of action, and an understanding of economically damaging levels of disease.

Good information is available for the first two points, but definition of an economic injury (or threshold) level is more difficult. Examination of the interaction between healthy leaf area duration and yield over several experiments in subtropical and tropical environments has failed to show a clear relation-ship, and it would appear that the relationship may best become understood through a modeling approach. Until that can be done, it appears that caution against the overuse of fungicides is advisable.

The Influence of Plant Population on Groundnut Growth and Yield Under Variable Water Supply

The effect of plant population on groundnut growth and yield performance was assessed in experiments conducted throughout Indonesia and in Australia. The optimum plant population for currently grown spanish cultivars was found to be about 250 000 plants ha^{-1} in Indonesia, while only about 90 000 plants ha^{-1} were needed to produce maximum pod yield at Kingaroy in Queensland, Australia. It was shown that the maximum plant size achievable in the absence of competition was 77 g in Indonesia, compared to 690 g in Australia. It was hypothesized that differences in the temperature and radiation environment affected growth and development, and led to these plant size differences. Clearly, a greater number of 'smaller' plants were needed to optimize yield in Indonesia compared to fewer 'larger' plants in Australia.

Drought stress of varying timing and severity was shown to substantially modify the response of plant population to pod yield as compared to that observed under well-watered conditions. In all cases, the optimum plant population for pod yield was lower under reduced water availability. In dense stands, rapid early water use resulted in more severe crop water deficits, which in turn reduced pod set and reproductive potential. The results have significant implications for future plant population recommendations for groundnut in Indonesia. Significant improvements in profitability could be made on-farm via reduced seed costs and increased yields under severe drought conditions.

A simple plant population model was useful in describing and analyzing groundnut response to plant population under variable water supply. With further development, it should become a useful tool to provide information on future plant population recommendations in Indonesia.

Investigation of Optimal Irrigation Strategies for Groundnut Using Scarce Supplies of Supplementary Irrigation

Dry season groundnut production is limited by lack of rainfall and irrigation water availability throughout much of South Sulawesi. The potential for widespread production of groundnut using supplementary irrigation derived from easily accessible groundwater is large. The research aimed to improve the efficiency of irrigation water application by assessing optimal irrigation timing and methods.

Results of the research clearly demonstrated that high pod yields (>2 t ha^{-1}) were achievable using less than full irrigation. For instance, irrigating at an interval of 15 days rather than 4 days produced similar pod yields. Reductions in irrigation frequency will reduce labor and fuel costs as well as improving the efficiency of rainfall utilization during the dry season.

It was apparent that infiltration of irrigation water was restricted at depths >20 cm, presumably because of poor surface soil structure associated with puddling during rice (*Oryza sativa*) culture. Deep tillage (to a depth of 40 cm) improved irrigation and rainfall penetration to deeper soil layers, and improved crop water status and total dry matter production. Pod yield responses to deep tillage were less evident. However, unusually high dry-season rainfall and high incidence of peanut stripe virus may have masked tillage treatment effects. Further research on the influence of deep tillage on groundnut pod yield performance is warranted in order to unambiguously determine any potential benefits.

Total dry matter production under rainfed conditions (in the absence of irrigation) was high (up to 3 t ha^{-1}) due to extensive exploitation of subsoil water reserves. Partitioning of dry matter to pods, however, was extremely poor and led to low pod yields. The potential for increased pod yields is large if cultivars capable of pegging and podding into dry and hard soils can be identified.

Development of a Groundnut Growth Model to Assist in Integration of Knowledge from Management and Adaptation Studies

To identify and quantify the major environmental constraints to groundnut production in Indonesia and Australia, a simple mechanistic model was developed. The model contains few, easily interpretable coefficients and mimics the main phenomena occurring at the crop level. The functions required for the model were derived from the management and adaptation studies conducted in other parts of the project. Pod yield was predicted from total biomass and harvest index. Harvest index was found to increase linearly with time after a genotype-specific amount of thermal time from sowing. Low harvest index was found to be the major reason for low yields in Indonesia. Biomass accumulation was related to radiation intercepted and canopy radiation use efficiency (RUE). RUE was reduced at minimum temperatures below 17°C. Intercepted radiation was calculated from leaf area index. A simple procedure was developed to predict leaf area from temperature effects on rate of production of nodes. Water limitation effects on leaf area growth and radiation use efficiency were incorporated in the model, but further testing of these components is required. Simulation analyses indicated that:

- Genotypes capable of expressing the harvest index potential of groundnut in Indonesia could increase pod yield two- to threefold;
- Genotypes with improved tolerance of RUE to minimum temperature could increase yield potential 10% at Kingaroy; and
- Earlier-maturing genotypes could reduce production risk at Kingaroy.

Further simulation analyses are required for better assessments of the utility of selecting for improved tolerance to minimum temperature and to determine the potential for use of earlier-maturing types at Kingaroy. We hypothesize that the cause of low harvest index in Indonesia is that the balance between growth and development causes a reduced pod load. This is associated with the low radiation and high temperature conditions of this environment. Further research is required to test this hypothesis, but because of the large potential gains, screening genotypes for higher harvest index in Indonesia should be pursued.

Preliminary Studies on Bacterial Wilt

While this short (6 month) project also addressed bacterial wilt of other crops, groundnut was the host of *Pseudomonas solanacearum* given most attention because bacterial wilt of groundnut is a serious disease in Indonesia (and China). This made Indonesia an ideal center from which to examine the problem from many aspects with a view to establishing priorities for future research. Dr Hayward, of the University of Queensland, worked at the Bogor Research Institute for Food Crops in collaboration with Dr M. Machmud and Mrs Hartini.

The objectives of the project were:

1. To prepare a review of the economic importance, host range, geographic distribution, and control of bacterial wilt;
2. To assess the present incidence and losses caused by bacterial wilt;
3. To develop screening procedures for evaluation of resistance to bacterial wilt in groundnut; and
4. In consultation with other regional scientists, to establish priorities for future research on bacterial wilt.

During this short project, a number of isolates from crop and weed hosts were preserved for future use in evaluation of resistance and measurement of virulence on various hosts. Many of these isolates were typed for race and biovar. Inoculation procedures for groundnut were standardized and compared, and (Indonesian) groundnut was assessed for disease reaction. The virulence of weed isolates on groundnuts was confirmed, suggesting one problem of disease control in poorly managed fields. The project developed the growing consensus that effective control of bacterial wilt involves disease-free sowing material, resistant germplasm, sanitation, control of weeds and nematodes, knowing the previous cropping history of the land, and using appropriate rotations, including flooding of either crop or fallow.

As a result of an ACIAR workshop on bacterial wilt held in the Philippines in 1985, a newsletter on biology and control of bacterial wilt was established, edited by Dr Hayward. The *Bacterial Wilt Newsletter* is issued twice per year, and can be sent to interested persons on request, free of cost.

This project worked in close coordination with the first phase of the groundnut improvement project in Indonesia, previously mentioned.

Improved Diagnosis and Control of Peanut Stripe Virus

This project originated as a logical extension of one of the findings of the groundnut improvement project in Indonesia. After examination of almost the entire world collection of groundnut germplasm held by ICRISAT, no groundnut lines resistant to peanut stripe virus (PStV) were found, but the effects of this virus were shown conclusively to be quite severe. This led to the proposal and ultimate approval of a project that aims to use molecular biology to produce groundnuts from the main Indonesian cultivar Gajah that will be resistant to this virus as a result of incorporation of the gene for the virus coat protein in the host.

The project opens a new area for ACIAR in that molecular biology techniques will be employed to provide novel means of plant virus resistance and agricultural diagnostics to aid developing countries. The commissioned organization, the Queensland Department of Primary Industries and its collaborator in Australia, the University of Queensland, will commence work on the project in January 1992. Collaboration with scientists in Indonesia has been established. They will be involved in all aspects of the project by means of regular visits for training in Australia and field testing of resistant plants in Indonesia. The project is scheduled to run for 3 years.

Increased groundnut production is a stated aim of the Indonesian Government, and PStV is seen as one of the significant constraints to increasing production at present. Increased production of groundnuts is important to the entire Indonesian economy, as some groundnut products are currently imported. Groundnut growing is an important small-holder enterprise. Similarly, removal of this constraint will have immediate benefits to countries throughout East and Southeast Asia where groundnuts are widely grown, and it could have important implications to many other countries as the potential for introduction of this virus in seed is great.

Prevention of yield loss is difficult, because the virus is both seedborne and aphid transmitted in a nonpersistent manner and has a wide host range. Currently available methods for detection of PStV are sensitive but cannot be used economically for large seed stock. This limitation of the methods precludes their use in screening the large seed stock for sowing healthy seeds. No sources of resistance to PStV have been found in cultivated groundnut even though numerous lines have been screened. Resistance to PStV has been identified in *Arachis duranensis* but crosses to introduce this trait have not been achieved. Therefore, genetic engineering appears to be the best and only possible option for producing commercial groundnut lines resistant to peanut stripe virus.

Genetic engineering offers the opportunity to improve existing cultivars by selectively adding specific new traits such as virus resistance. The most successful strategy to date for the control of plant viruses is the expression of viral coat protein genes in transgenic plants. For plant viruses belonging to ten different taxonomic groups this has consistently been shown to protect against infection from the corresponding virus. No yield losses have been observed after virus infection of those transgenic plants in the field, and the intrinsic agricultural traits of the cultivars have been preserved. Coat protein-mediated resistance has been used successfully in controlling other members of the potyvirus group, e.g., potato virus Y (PVY) in potato (*Solanum tuberosum*) and soybean mosaic virus in soybean (*Glycine* max). Field testing and evaluation of several transformed plant species is currently in progress in at least ten countries around the world. Effective virus resistance under field conditions has been reported to PVY, potato virus X, and potato leafroll virus in potato, alfalfa mosaic virus in tobacco (*Nicotiana tabacum*), and tomato mosaic virus and tobacco mosaic virus in tomato (*Lycopersicon esculentum*).

Significant progress has been made in the development of gene transfer systems that allow stable introduction and expression of foreign genes in plants, including legumes, using gene transfer mediated by either *Agrobacterium* or DNA-coated microprojectiles. Dr R.G. Birch has already established conditions for efficient gene transfer into groundnut and has demonstrated that groundnut embryos can be regenerated into intact plants after bombardment with microprojectiles.

The principal aim of the project is to generate genetically engineered transgenic groundnut plants resistant to peanut stripe virus. We intend to propagate and purify a single local-lesion isolate of PStV from Indonesia and clone its genomic RNA. Complementary DNA clones harboring the viral coat protein gene will be identified and the nucleotide sequence determined. A translational start codon and regulatory sequences for gene expression in the plant host will be introduced into the coat protein gene construct.

In parallel, a gene transfer and plant regeneration system for the commercial Indonesian groundnut cultivar Gajah will be developed using marker genes. First, embryo culture and the parameters for microprojectile bombardment will be optimized, to give stable transfer into cells suitable for regeneration. Second, a sensitive, non-toxic assay will be developed to facilitate regeneration of uniformly transformed groundnut plants from single transformed cells.

Once developed, the techniques will be used to transfer the gene controlling synthesis of PStV coat protein into groundnut cells, and to regenerate transformed plants. Transformed plants and their progeny will be assayed for the expression of the viral coat protein gene and evaluated for PStV resistance.

F_2 progeny of virus-resistant lines will be evaluated under field conditions in Indonesia. Scientists from Indonesia will be trained in molecular biological techniques to enable them to undertake that evaluation in Indonesia. They will challenge the plants with natural and/or artificial epidemics of the virus, and replication of the virus will be analyzed.

To improve the detection and identification of PStV in seeds and plant material, we will develop a user-friendly nonradioactive nucleic acid probe, taking advantage of the cDNA library of the PStV genome generated during the earlier steps in this project.

The expected benefits from the project include:

1. An increase in productivity can be expected when growing groundnuts resistant to PStV. Reduction of yield losses will increase returns from resistant crops and encourage growers to return to groundnut production. The reduction in the amount of inoculum in commercial crops will lessen the pressure from this disease on susceptible crops. Commercial release of resistant groundnuts can be expected in the medium term (5–10 years).
2. The availability of a gene transfer system for groundnuts that will make possible other genetic improvements, for example, resistance to other diseases and pests, or improved nutritional value. A possible broad-spectrum resistance to other potyviruses that cause losses in groundnut crops (such as peanut mottle virus, which is also seedborne) could be an additional benefit of the research.
3. In the short term, the use of a sensitive and reliable nucleic acid probe will avoid sowing of infected seed lots and ease the movement of groundnut seeds between countries.
4. Scientists from Indonesia will be trained in molecular biological techniques, to evaluate transgenic groundnut plants during field tests in their home country, and enable them to conduct further research into plant virus control at the molecular level.

Selection for Water Use Efficiency in Food Legumes

This proposed area of research also arose as a recommendation from the review of the groundnut improvement project in Indonesia. World agricultural productivity is limited by water availability. In particular, drought stress limits yield of nonirrigated food legumes in Australia and many developing countries throughout the semi-arid tropics. Apart from irrigating in dry environments or farming in humid areas where water is not limiting, selection and breeding of plants that are resistant to drought is one of the few avenues available to improve crop productivity. Breeding cultivars that have superior performance under water-limited conditions is currently done by selecting solely for pod or seed yield. This approach is costly in terms of space, time, and resources. Plant breeders and crop physiologists now believe better-adapted and higher-yielding cultivars could be bred more efficiently by identifying reliable traits of drought resistance to complement conventional breeding programs.

Improvement in water use efficiency (W, g total biomass kg^{-1} water transpired) is one such trait that can increase yield when water resources are scarce. Until recently, it was widely accepted that no intraspecies variation in W existed. However, recent research in ACIAR's legume water use efficiency project and groundnut improvement project in Indonesia have shown that highly significant variation in W exists among cultivars of groundnut, cowpea (*Vigna unguiculata*), sunflower (*Helianthus annuus*), barley (*Hordeum vulgare*), wheat (*Triticum aestivum*), and cotton (*Gossypium* sp).

Until now, it has been virtually impossible to include W in breeding programs due to difficulty in measuring it in glasshouse and field conditions. Research in the above-mentioned projects has demonstrated that carbon isotopic composition (Δ) is well correlated with W, and raised the possibility of using Δ as a rapid, but relatively inexpensive, technique for selection of W in breeding programs.

More detailed experiments during the groundnut improvement project provided unequivocal evidence that W and Δ were well correlated in diverse groundnut cultivars grown under well-watered and water-limited conditions in the field. In addition, genetic studies showed Δ is highly heritable ($h^2 = 0.81$) and had small genotype × environment interaction, indicating that the potential for its selection was good.

Interestingly, it was also shown that specific leaf area (SLA, cm^2 g^{-1}), or 'leaf thickness', was extremely well correlated with W ($r^2 = 0.76$), and with Δ over a wide range of cultivars and environments. This observation highlighted the possibility of using SLA as an even more rapid and inexpensive technique for selection of W. This finding has significant implications for groundnut breeding programs in developing countries where access to, and resources to purchase and maintain, mass spectrometers are limited. The extent of this correlation in other food legumes also needs to be investigated as a potential selection index for W.

Being able to measure W on a wider range of groundnut cultivars has made it possible to detect an apparent negative association between W and harvest index (HI, that is, the proportion of total biomass partitioned to seeds or pods). Although the range of germplasm tested was relatively small, a consistent trend was observed in a number of glasshouse and field studies. A very preliminary crossing program showed that the negative association was consistent through to the F_4 generation, and no evidence that the linkage could be broken by breeding was found. The moderate strength of the negative correlation between W and HI in this study ($r^2 = 0.30$) and a similar genetic study conducted earlier in the project suggests that concurrent improvement in these traits may be difficult, but it should be possible. Indeed, it should be possible to break this association since cultivars such as UF78114-3 and VB-81 have moderately large W and HI. Further research to understand the nature of this correlation is needed before selection based solely on W can be recommended. On the basis of our preliminary findings, selection for low Δ or low SLA may improve total biomass, while having minor impact on pod yield. Such information may, however, be appropriate in some developing countries where both pod yield for human consumption and vegetative yield for animal fodder need to be maximized.

Close collaborative links with the groundnut drought physiology program at ICRISAT have been formed over the past few years. The groundnut breeding program at ICRISAT is vitally concerned with identifying traits for selection of improved yield performance under drought, and staff have linked closely with the ACIAR groundnut project on progress on the water use efficiency research. The time is now right to establish a selection program using the significant findings made in the previous groundnut improvement projects. ICRISAT is well situated and resourced to conduct this breeding and screening work so that more water use efficient cultivars can be tested and ultimately made available to countries throughout the semi-arid tropics.

It is envisaged that the project will collaborate with the national programs in India (with linkages to ICRISAT on the groundnut and chickpea research), and Thailand (via linkages with the recently funded ACIAR project on soybean improvement in Thailand). Research into the extent of variation in, and potential for exploitation of, W has not been conducted in soybean or chickpea. Indeed with soybean, the proposed project would complement other approaches to the problem of drought currently being addressed in the ACIAR Soybean Project (e.g., phenology and leaf epidermal resistance).

The objectives of the proposed collaboration are:

1. To identify or select groundnut cultivars with high W (using SLA as a selection trait for W) and HI from the world germplasm collection, or from among progenies in the ICRISAT breeding program. Depending on the success in identifying cultivars with high W and HI, it may be necessary to initiate a hybridization program to attempt to combine these traits.
2. To evaluate the yield performance of these parent lines or progeny in appropriate target environments throughout the semi-arid tropics.
3. To determine the extent of cultivar variation in W (and its correlation with Δ and SLA), HI, and the relationship of these traits to grain yield in other food legumes (e.g., soybean and chickpea). This would allow assessment of these traits as possible selection criteria in breeding programs to improve adaptation to water limited environments.

Boron Nutrition in Groundnuts

Scientists from Murdoch University in Perth, Western Australia, and from Thailand conducted research for 6 years into micronutrient deficiencies into food legumes, and concluded that boron (B) deficiency is widespread in groundnut crops in many upland and lowland soils of northeast, north, central, and southeast Thailand. The deficiency was considered a potentially serious constraint to improved seed production and quality in groundnuts and all other legume crops. These effects were particularly severe in the area of seed production and seed quality. Seeds produced under low B levels had low germination capacity and grew poorly in the early stages. In groundnut, seed low in boron suffered from accelerated loss of viability during storage. These effects mean that farmers sowing seed produced on soil low in B might suffer from poor crop establishment, increased weed competition, and the need to plant higher quantities of seed to establish their crops.

Aflatoxin in Groundnuts

ACIAR has not yet supported a project specifically addressing this problem, but its postharvest project on fungi and mycotoxins in Asian foods and feeds has included groundnuts for human consumption and as an animal feed within its scope. Studies carried out in Thailand in this project have shown that levels of aflatoxins in Thai groundnuts and maize are the major sources of aflatoxins in human and animal diets. The problem of aflatoxins in foods and feeds in tropical countries remains in urgent need of attention, both on economic and medical grounds. As a result, further activity in this area has been approved.

Specific objectives of the research include the monitoring of groundnut crops for the presence of *Aspergillus flavus* from the time of sowing through pod development, harvest, and storage; assessment of the development of aflatoxins in the seeds throughout their growth; determination of the comparative distribution of *A. flavus* and *A. parasiticus* in Thai groundnuts and soils; and assessment of the efficacy of techniques for reducing *A. flavus* invasion under Asian field conditions.

Training

While formal training is not within the terms of reference of ACIAR, all ACIAR projects attempt to include practical development of the research capacity of collaborators from the developing countries, as demonstrated by the projects described earlier. This takes many forms, from interaction with their Australian counterparts to workplace experience in Australia working on the project. In addition, a number of formal Australian International Development Assistance Bureau (AIDAB) Fellowships are reserved for developing country scientists working on ACIAR projects. These fellowships enable selected scientists to undertake postgraduate studies at Australian universities, towards Masters or Ph.D. degrees. Several scientists working on groundnut projects have been selected for study in Australia.

Linkages

ACIAR projects are not conducted in isolation. In addition to the scientists from the developing countries and from Australia, in many instances other scientists from other countries are invited to take part when the joint effort will expedite the research. The CGIAR centers, particularly ICRISAT, have been closely involved with groundnut research supported by ACIAR. In addition, groups such as the Peanut Collaborative Research Support Program, the Philippines Council for Agriculture and Resource Development, the Oil Crops Research Institute of Chinese Academy of Agricultural Sciences, the International Benchmark Sites Network for Agrotechnology Transfer, and AIDAB can become involved in joint research. In particular, AIDAB Special Purpose Grants to CGIAR Centers can often be used to supplement existing ACIAR projects, as happened with peanut stripe virus resistance screening in Indonesia and a groundnut bacterial wilt workshop held in Malaysia in 1990. In addition, the *Food Legume Newsletter* is published by ACIAR to strengthen informal linkages among food legume scientists.

A British Perspective on Groundnut Research

J.C. Davies[1]

Abstract

*The United Kingdom has had a long involvement with the production, storage, and utilization of groundnuts (*Arachis hypogaea*). This has been and continues to be supported by research effort. The paper describes the rationale for Overseas Development Administration (ODA) support for groundnut research in developing countries, its current scope, and prospects for the future within the Consultative Group on International Agricultural Research (CGIAR) and through bilateral linkage in the light of significant recent developments in management and strategic planning of ODA Research and Development activity.*

Résumé

***Une perspective britannique sur la recherche arachidière:** Le Royaume-Uni joue depuis longtemps un rôle dans la production, le stockage et l'utilisation de l'arachide (*Arachis hypogaea*). Cette activité a été et continue à être appuyée par des recherches. La communication décrit les raisons d'être de l'appui assuré par le Ministère du développement d'Outre-mer (ODA) à la recherche arachidière dans les pays en développement. Sont également discutées sa portée actuelle et ses possibilités d'avenir dans le cadre du Groupe consultatif pour la recherche agricole internationale (CGIAR) et par des liens bilatéraux à la lumière des progrès effectués récemment dans les domaines de la gestion et de la planification stratégique des activités de recherche et de développement de l'ODA.*

The British are no strangers to the groundnut (*Arachis hypogaea*) crop – one could go as far as to say that we still hear echoing in the Aid corridors the cry "Remember the African groundnut schemes". These schemes certainly underscored the importance of research in considering what is both a valuable and fickle legume – or is it oilseed? – a lesson that still colors our strategic research thinking. The crop is certainly one with which I have more than a nodding acquaintance. I suspect I have examined rather more groundnut pegs for signs of rosette damage in my youth than I now have hairs left on my head. I think my knees still bear the scars of the crawls along groundnut rows to count aphid colonies and their status. It is a fascinating crop and I envy you your continuing enjoyment of it.

Now, I look at the crop with a donor's eyes. Donors are pretty familiar with the crop's agronomic and nutritional virtues, and its place in the farming systems of Africa, Asia, and Latin America. I do not think any donor doubts its developmental value either – but where does it stand in our overall strategies?

The Rationale for ODA Support for Groundnut Research

Recently ODA, after a long, frank, and meaningful dialogue with the UK scientific community and our own advisers and economists, developed a Renewable Natural Resources Research Strategy (ODA 1990). This, naturally, as is expected for all proposals for research, assessed production and socioeconomic data, attempted to gauge current and future demands, importance to developing countries, and marketing and other constraints to development of the tropical

1. Deputy Chief Natural Resources Adviser, Overseas Development Administration, 94 Victoria Street, London SW1E 5JL, UK.

Davies, J.C. 1992. A British perspective on groundnut research. Pages 205–210 *in* Groundnut – a global perspective: proceedings of an international workshop, 25–29 Nov 1991, ICRISAT Center, India (Nigam, S.N., ed.). Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

crops against a set of cross-cutting issues where UK appeared to have comparative advantage. More general concerns on poverty alleviation, sustainability of global natural resources, and researchability were also of necessity part of this dialogue. Importantly, as far as groundnut is concerned, the review considered among other cross-cutting issues, Integrated Pest Management (IPM), Resource Assessment and Farming Systems (RAFS), Food Science and Crop Utilization (FSCU), Plant Science, and Biotechnology. The outcome was a clear Priority 1 for groundnuts under the oilseeds and edible seeds category. This resulted in a substantial percentage allocation of our research funding under each of the above headings for research on oilseeds (Table 1).

Within oilseeds, given ODA's overall concerns for Africa south of the Sahara, rural poverty, and small holders, groundnuts were identified as giving the best option for meeting forecasted edible oil deficits. Their versatility within farming systems involving crops and animals and existing, but declining, potential as an export crop were added factors in favor.

A Priority 1 is all very well – but what could the UK add to the global effort and where could we catalyze or improve current, much larger, research inputs made in areas where the crop is actually grown, either in the developed or developing world? We were struck by the very significant amount of effort being devoted to the crop both in countries in the developed world, such as the USA, and developing world, such as India. The choices had to be pragmatic and realistic. Nevertheless, we concluded that there were subjects on which, by any sensible assessment, the UK could contribute. The analysis underlined decisions to continue some existing linkage work, while highlighting newer potential areas of collaboration in this age of biotechnology and eco-regional/farming systems perspectives.

Table 1. Percentage and total cash allocations to the Oilseeds Commodity Group.

	Funding (%)	Cash allocation (£)[1]
Integrated Pest Management	2.2	500 000
Resource Assessment and Farming Systems	0.7	158 000
Food Science and Crop Utilization	0.1	250 000
Plant Science	0.2	158 000
Biotechnology	0.4	90 000

1. £1 = US$ 1.60

There has been a long tradition of support for groundnut breeding through introduction of wild species crossing and genetic studies at Reading University. This was logical in view of the fact that the UK does not grow the crop, thus reducing problems of a phytosanitary nature. The new strategy draws out the importance of continuing effort to broaden the narrow genetic base for durable resistance to the major global diseases and pests. Potential opportunities were also identified for work on drought and on soil moisture and physical soil characteristics as they affect breeding strategy. The value of existing UK competence in the general area of postharvest management and crop utilization was reaffirmed – particular strengths exist in aflatoxin studies, storage insect control, harvesting, and storage. Priority was also assigned to the potential 'add on' to work in the area of vector/virus interface.

The Current UK Effort on Groundnuts

Government commitment to overseas aid from the UK remains strong and is particularly targeted towards British Commonwealth countries for historical reasons. There is a recognized need to also focus on sub-Sahelian and southern Africa on poverty alleviation and environmental grounds. However, as a former scientific practitioner, I am concerned by the apparent inability to fully harness the available funding sources to renewable natural resources (RNR), generally, and RNR research, in particular. There is a detectable gap in the agreement achieved between the RNR scientists and administrators, and this exists in both developing and developed countries. There is often a significant congruence of views among scientists, such as here in this gathering, on the need for research in RNR to be given priority! However, the ability to enthuse Ministries of Planning and Treasuries in developing countries and administrators in the aid programs of developed countries for appropriate allocations for research effort is less apparent. This is not the forum to debate this, but it is a serious issue. It is related to the importance of focusing on development problems in order to solve the big challenges facing developing countries. It behooves us all, therefore, scientists, research managers, and administrators, to, from time to time, step back, re-review our priorities, and focus on outputs and solutions, not merely inputs and science. At all levels we are in the arena of service and not a cause, when we consider the level of resources available and the relatively short period of time available to provide relevant and workable solutions for the burgeoning populations. We have to increasingly acknowledge the established relationship between poverty and environmental degradation of vital and basic resources such as forests, soil, and water in our planning.

Be that as it may, there is significant UK current effort – mainly from R&D funding – for work on groundnuts. As examples of this I might quote work on rosette virus, bud necrosis, and resistance mechanisms (See Table 2).

Additional support also flows from UK international funding sources to international research effort in the Consultative Group on International Agricultural Research (CGIAR) (£8 400 000 in 1991/92) (£1 = US$ 1.60) and thus indirectly to groundnut research, through our core support for ICRISAT, which over the past few years has increased from £660 000 in 1983/84 to £960 000 in 1991/92.

Perhaps surprisingly, given the importance of the crop, relatively little funding can be identified either for research or development of the crop from UK bilateral sources. In the latest annual report of R&D, some funding can be identified for country-specific work, for example, work on moisture conservation in maize (*Zea mays*)/groundnut (Twomlow and Wilcox 1990), mycotoxins in animal feed, and small-scale extraction of oil from groundnuts. The demand-led element of bilateral assistance means that additional work will not be funded unless governments give priority to such work in their programs and strategies. In your deliberations here today and for the rest of the week it would be useful to give a little thought to this. It is a relatively fruitless exercise to preach to the converted – you need a few more converts, if the amount of groundnut research and research in general is going to be stepped up through provision of additional funding from bilateral donor sources.

Table 2. Current research effort in UK funded by ODA, involving groundnuts.

Integrated Pest Management
Component viruses of groundnut rosette
Resistance to vectors of groundnut bud necrosis
Phytoalexin production in groundnuts
Control of resistance mechanisms in groundnuts
Mechanisms of resistance to *Lepidoptera* in groundnuts
Pests of annual fruit, flowers, and seeds
Food crop pests in East Africa
Plant phloem in relation to insect pest resistance
Crop protection in rain-fed farming in India
Food Science and Crop Utilization
Control of mycotoxins in oilseeds
Mycotoxins in livestock feed in Pakistan
Mycotoxins in livestock feed in India
Development of microbiological quality control methods
Small-scale oil extraction from groundnuts
Fuel use of groundnut shells
Development of a yeast bioassay for mycotoxins

Future Scenarios for Donors – Realities, Prospects, and Opportunities

I would like to be in a position to look into a crystal ball and see what the future holds in store for groundnuts. In a rapidly changing world, however, all a donor can do is to look at probabilities, exciting possibilities, recent research outputs, and current efforts. On the latter I have already learnt a lot from this gathering; on the research outputs I have questions and on the future I have only optimism.

From a UK perspective, we continue to see the crop as having a major role as a commodity in the internal economies of many of the main recipient countries of ODA funds, particularly in Africa and Asia. We do not visualize that the crop will receive a lower priority in the updating of our strategy, which will occur in 1992. The crop has continuing importance in the nutrition of urban and farm families, will not decline in importance in local trading and internal economy, and obviously retains its versatility as a base for an extensive range of food products that are critically important for people who rate a high profile in ODA's poverty focus. We are less sure of the crop's role in the developing donor and recipient country concerns on environment. Byproducts, such as haulms, have a significant role in livestock nutrition in some areas, with consequent recycling implications. Husks have a role as fuel and the nitrogen fixing ability is acknowledged – all have sustainability and environmental implications. On the face of it is all very positive – but what of the clean weeding soil erosion aspects? Do we need more understandable assessments of research outputs on these aspects for policy makers and funders? Are the problems really being addressed from these angles? The rapid strides in genetic manipulation mean that much can be expected from research targeted to advances in tissue culture technology and biotechnology and thus to utilization of positively identified stress resistance characteristics from the germplasm, backed by a more complete understanding of the genetics of the crop. However, it is almost impossible to calculate the effects of any of these technical innovations on production figures from past success stories from research. Utilizing past economic projections is difficult in the absence of sound data on what success may be achieved from these novel methods in production terms. This makes resource allocation for research in these areas little more than "casting bread on the waters". In taking decisions on such investment on research there are wild cards for donors. Yes, there is an unsatisfied demand globally for oil and oilseeds. However, world production of soybean (*Glycine max*) (and possibly other vegetable oils) might become so large that the 'value for money' aid-recipient countries would get from additional investment in groundnut research would be negligible. Factors such as the labor-intensive nature of the groundnut crop and difficulties of drying and storage of decorticated seeds also have important and possibly negative implications for its future in sustainable development in developing countries. Donors will have to be guided by clear strategies formulated and consistently implemented by recipient governments. There is therefore a challenge to you, the participants here, to review again the **real** constraints to the crop and to give clear signals on genuine demand-led research priorities – is it food, is it oil, is it oil quality, are the top constraints caused by disease factors or soil, for instance? How do we set priorities for research for different ecoregions? The fact is that everything cannot be funded and choices have to be made.

If I was a skeptic here, I might ask what has been the value of the very considerable effort put in at ICRISAT on groundnuts over the past 15-plus years to the small farmer of the semi-arid tropics. I am aware of the release of some improved cultivars produced by breeding, screening, utilization of the germplasm, etc., but what of the more 'research-led' aspects? There have been some fascinating papers but do we have at this moment good convincing figures that I can wave at my masters of the value of research in problem solving?. I look forward to obtaining in tomorrow's session clear evidence that will disarm the more skeptical of my colleagues on the 'desks' and even some of my technical colleagues who have spent time at the sharp end of research in developing countries utilizing materials and advice from the CGIAR system. It is important at this juncture that outputs are identified and a useful 'story' put together in crops other than rice (*Oryza sativa*) and wheat (*Triticum aestivum*). No-one expected miracles in the drier less-controlled crop environments of the SAT but programs are now coming of age and broad conclusions and comparisons identifying commodities, systems, and technologies where research investment has paid off will be made – if only to identify areas where more investment in research is likely to pay-off.

The Future for International Groundnut Research in Developing Countries

I am now going to be provocative and perhaps be a little bit of a devil's advocate.

The 1980 symposium (ICRISAT 1980) provided clear general guidelines for taking forward research on groundnuts emphasizing ICRISAT's global role as a center for their genetic improvement, developing farming systems, and yield improvement to stabilize production. The overall mandate and the importance of making more effective use of natural and human resources, and identifying socioeconomic and other constraints to development and means of alleviating them was highlighted. The symposium also stressed assistance to NARS. It further defined these general goals and introduced ICRISAT's cooperative program on groundnuts in both research and training. Specific global Research Goals were listed as:

Breeding for:
- Resistances to disease;
- Earliness, high yield, and farming systems;
- Increasing BN fixation; and

Exploiting:
- Wild species; and
- Physiological characteristics.

Emphasis was clearly on the breeding and germplasm base. Relatively little was said about the detailed contribution of many discipline areas involved in achieving these goals and the strategy for setting priorities for research among them. The usual associated linkage and training activities were listed.

In the interim one cannot be but impressed with the number of workshops and meetings on various aspects of the crop that have been held – for instance, four workshops in southern Africa, four meetings of the consultative group on groundnut rosette, meetings on peanut stripe, etc. A glance at the papers produced at these meetings indicates the range of work in progress from the ultra sophisticated work on the RNA of rosette viruses through development of genetic markers to phosphorus nutrition of the crop to simple time of sowing trials. As a Donor however, and increasingly as someone with a role in attempting to 'sell' the products (and value) of **international** research to others who control purse strings and are seeking to obtain better value for their development money, it is disconcertingly difficult to cull out the nuggets of value from **international** research. What does a Donor make of such conclusions as:

"Development of cultural practices [in groundnuts] to accelerate absorption of P and its efficient transfer to reproductive organs during later growth stages is highly recommended,"

having earlier been told something that was not exactly new, i.e., legumes have a high P requirement due to the production of protein-containing compounds of which N&P are important constituents? or,

"The disease [peanut stunt] is **apparently** of economic significance?"

While acknowledging the extraordinary scientific progress on understanding groundnut viruses, particularly rosette, to find that the technology has lead to very little actual change in recommendations to farmers or, indeed, release of rosette-resistant seed material, is sobering. I hope to be convinced here that I am really behind the times, but I wonder, having recently read Subrahmanyam et al. (1991). After all, we were talking about rosette-resistant material and using resistance sources in breeding programs in Uganda in the 1960s – albeit, rather inadequately in view of *very* severe financial constraints. In hindsight, now I wonder if possibly the relatively small amounts we allocated in northern and eastern Uganda was not about right. Perhaps we did have our priorities right and the work on rosette disease was a trifle supply driven. The international system was meant to assist the NARS in reaching conclusions on some of these difficult priority-setting questions, I believe, and to provide a broad-based range of genetic material and technology options for tackling them.

While there is no question that improved cultivars from breeding programs are feeding through to national systems – India, Sudan, Ethiopia, and Malawi are cases in point – there are disconcertingly few comparative production figures, other than from small controlled trials, that can be used to encourage loosening of purse strings for schemes for rapid multiplication and wide utilization of such lines. In current circumstances governments or commerce in developing countries need these, and scientists, despite their inclinations, have to be a little more PR-conscious. Perhaps this is unfair comment, since this could be seen as a country program and not an international responsibility. The problem is that without stimulation from researchers little is likely to happen.

Should international research institutions really be working on use of chemicals for seed dressing? Should we really be into use of carbofuran on groundnuts in West Africa? Are these 'problems' not ones for national systems?

One gets a sense of a large number of research scientists increasingly in touch with each other at an international level. However, the question being asked (and not only with groundnuts) is: to what end, as far as the national systems and farmer is concerned? Are the bottlenecks to progress really nothing to do with the 'research gap', but instead related to policy and infrastructure, including marketing and transport, seed multiplication, and running costs for adaptive research carried out ecoregionally by NARS? The logic of a positive answer here is for donors to put more of their money into these activities. Are we right with our international research targets? Should not these broader aspects be the issues tackled from the bottom up with international technical and financial assistance? Should then the investment at this time really be in increasingly esoteric research? Or should it be in 'kick starting' production to ensure the financial sustainability of NARS research? We must be prepared to ask and give guidance on these and other policy questions with confidence as a result of this meeting. Priority increasingly is in finding solutions to the problems of producing groundnuts, not to solutions of interesting research problems. Is the goal more multipurpose groundnuts for farm families, oilseeds, or confectionery groundnuts, and in what sort of mix? It calls for a real multidisciplinary planning effort to attack these issues. If we avoid these questions we are on a course of increasing risk strategy as far as international and, by implication, national research is concerned.

I am convinced that very useful and applicable results are being produced in a whole range of subject areas by the international system. But where is the synthesis and clear prioritization, and where are the advanced 'strategic' papers for the informed developing and developed country administrator who might be persuaded to invest in research on the crop by a reasoned argument incorporating facts and figures, technical and economic, on the production, marketing, utilization, and development score?

May I make a final plea for a more lateral thinking at this time on the part of research managers.

We need less concentration on interesting researchable topics, or, as a minimum, we need to link these more closely to production and practical recommendations to other researchers or farmers. The groundnut crop must be seen as a component of the total agricultural system and the problems much more clearly quantified in terms of loss of production within the functional agricultural system – we are all familiar with the 150% yield loss syndrome! The "unpredictable legume" is undoubtedly more predictable thanks to the large investment in research. However, the question is, where should funding and effort be applied to make the crop even more predictable for the benefit of small farmers, the rural and urban poor, and, of course, the basic economics of developing nations that grow the crop?

References

ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1980. Proceedings of the International Workshop on Groundnuts, 13-17 Oct 1980, ICRISAT Center, India. Patancheru, A.P. 502 324, India: ICRISAT.

ODA (Overseas Development Administration). 1990. A strategy for research on researchable natural resources. London, UK: ODA.

Subrahmanyam, P., Greenberg, D.C., Savary, S., and **Bose, J.P.** 1991. Diseases of groundnuts in West Africa and their management: research priorities and strategies. Tropical Pest Management 37(3):259-269.

Twomlow, G., and Wilcox, T. 1990. Conservation and tillage. Cyclostyled reports LD/90/21 and OD/90/24. Silsoe, UK: National Agricultural Institute of Engineering.

Groundnut Research at CIRAD

R. Schilling[1]

Abstract

*The Institut de recherches pour les huiles et oléagineux (IRHO), the Oil Crops Department of the Centre de coopération internationale en recherche agronomique pour le développement (CIRAD), is a French organization specializing in applied research and development for tropical oil crops, including groundnut (*Arachis hypogaea*). Its operations cover all stages of the producer-consumer chain, from creation of sowing material to packaging and export of finished groundnut products. They take three main forms: research bases where work of strategic interest is conducted, research-development programs, and support to agricultural and agroindustrial development. Current programs are concentrating on agronomy, breeding, crop protection, technology, and development. Permanent installations are located in France (2 full-time staff) and Africa (14 full-time staff). The groundnut program is being conducted in close liaison with our African partners and in cooperation with specialized French organizations, the Institut français de recherche scientifique pour le développement en coopération (ORSTOM) and the Institut national de la recherche agronomique (INRA), foreign organizations (in the USA, the UK, etc.), and international organizations (primarily ICRISAT). The annual crops programs, including groundnut, will be brought together under the new structures of CIRAD in the near future.*

Résumé

Recherche arachidière au CIRAD: *L'Institut de recherches pour les huiles et oléagineux (IRHO), département sur les cultures oléagineuses du Centre de coopération internationale en recherche agronomique pour le développement (CIRAD) est une organisation française qui se spécialise sur la recherche appliquée et le développement des cultures oléagineuses tropicales y compris l'arachide (*Arachis hypogaea*). Ses opérations sur cette culture couvrent toutes les étapes de la chaîne producteur-consommateur, à partir de la création de matériel de semis jusqu'au conditionnement et à l'exportation du produit fini. Ses activités revêtent trois formes principales: bases de recherche où du travail d'intérêt stratégique est effectué; programmes recherche-développement; appui aux développements agricoles et agro-industriels. Les programmes actuellement en cours sont axés sur l'agrononie, la sélection, la protection des cultures, la technologie et le développement. Des installations permanentes sont situées en France (2 agents à temps complet) et en Afrique (14 agents à temps complet). Le programme arachidier est réalisé en liaison étroite avec nos collègues africains et en coopération avec des organisations françaises spécialisées telles que l'Institut français de recherche scientifique pour le développement en coopération (ORSTOM), l'Institut national de la recherche agronomique (INRA), des organisations étrangères (aux Etats-Unis, au Royaume-Uni, etc) et des organisations internationales (surtout l'ICRISAT). Les programmes sur les cultures annuelles, y compris l'arachide, seront rassemblées sans tarder dans le cadre des nouvelles structures du CIRAD.*

1. Deputy Director, Annual Oilcrops Division, Institut de recherches pour les huiles et oléagineux (IRHO), Centre de coopération internationale en recherche agronomique pour le développement (CIRAD), 13 Square Pétrarque, 75116 Paris, France.

Schilling, R. 1992. Groundnut research at CIRAD. Pages 211–219 *in* Groundnut – a global perspective: proceedings of an international workshop, 25–29 Nov 1991, ICRISAT Center, India (Nigam, S.N., ed.). Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

CIRAD

The Centre de coopération internationale en recherche agronomique pour le développement (CIRAD) is a center for international cooperation in development-oriented agricultural research, with emphasis on tropical and subtropical zones.

Its objectives are to contribute to the development of these regions through research, experiments, training, and information dissemination; to assist national agricultural research systems at the request of host countries; and to contribute, through an analysis of future scenarios, to the development of policies related to its mandate areas and crops.

CIRAD was formed through the merger of French agricultural, veterinary, forestry, and food technology research institutes specializing in hot regions, from which it acquired the vast heritage of French tropical agricultural research. The organizational model was that of commodity-based institutes with activities ranging from research to development, involving national authorities, farmers, and industry. They were brought together initially in 1970 and CIRAD was set up in 1984. A central research center has been built in Montpellier (southern France), but most CIRAD scientists are usually assigned to national teams overseas, under general or bilateral agreements that specify the characteristics of the program, respective commitments, and duration.

CIRAD's management units are also evidence of this international cooperation. Our partners are represented on the Scientific Advisory Committee, program committees, and in external reviews. The staff by-laws allow recruitment of foreign scientists. Most of the research activities are decided by bilateral commissions including France and cooperating tropical countries.

Organization

The principles underlying CIRAD's organization and operation are dictated by its background. It is a single establishment, but its activities are decentralized.

There can only be one legal entity, and therefore only one establishment with a budget, an accounting system, and personnel by-laws for the entire organization.

The Chairman of the Board of Trustees represents the Center and the Director General is responsible for its commitments vis-à-vis its partners. In practice, both these responsibilities are largely delegated to the 11 departments who have considerable autonomy for initiative and action. Decentralization has enabled the departments to conserve the individual culture and work styles of the former institutes, but need has emerged for closer coordination, so that both perennial crops and annual crops will be brought together under the new structures of CIRAD in the near future.

The departments

Eight departments conduct commodity-based research:

- Food crops department, Institut de recherches agronomiques tropicales et des cultures vivrières (IRAT);
- Citrus and other fruits department, Institut de recherches sur les fruits et agrumes (IRFA);
- Oil crops department, Institut de recherches pour les huiles et oléagineux (IRHO);
- Stimulant crops department, Institut de recherches du café, du cacao et autres plantes stimulantes (IRCC);
- Textile crops department, Institut de recherches du coton et des textiles exotiques (IRCT);
- Rubber department, Institut de recherches sur le caoutchouc (IRCA);
- Wood and forestry department, Centre technique forestier tropical (CTFT); and
- Livestock production and veterinary medicine department, Institut d'élevage et de médécine vétérinaire des pays tropicaux (IEMVT).

Two departments conduct theme-based research:

- Agrarian and farming systems, Département des systèmes agraires (DSA); and
- Agricultural equipment and technology, Centre d'études et d'expérimentation en mécanisation agricole et technologie alimentaire (CEEMAT).

One department is responsible for horizontal programs and general services:

- Management research, documentation, and technical support department, Gestion recherche documentation et appui technique (GERDAT).

The programs

The 11 departments conduct a total of 39 research programs. The programs reflect the approach of the departments that manage them. They either concern commodities [e.g., the rice (*Oryza sativa*) program, banana (*Musa paradisiaca*) program, and oil palm (*Elaeis guineensis*) program] or priority themes and areas, where CIRAD has special experience (e.g., the agroforestry program, food technology and engineering program, and grasshopper and locust program). They form the basis of CIRAD's scientific organization.

Scientific coordination groups

Scientific coordination of the research programs of the different departments is the task of five discipline-based groups: environment analysis and improvement, general agronomy; crop analysis and improvement; crop protection; postharvest technology; and economics and sociology.

In addition, two other similar units conduct center-level operations, one for remote sensing and the other for biometry.

The scientific coordination groups stimulate circulation of scientific and technical information, supervise initial and continuing training of scientists, and study and initiate new and innovative research programs of common interest. They play an important role in interaction with CIRAD's collaborators.

Staff

CIRAD employs 1900 people, including 900 senior scientists and administrators, who work in about 50 countries. There are 400 scientists working in France (100 in the overseas departments and territories) and 500 in other countries.

IRHO

IRHO was set up in 1942 as a private, nonprofit association, and since 1 January 1985, under the name IRHO/CIRAD, it has been the oil crops department of CIRAD, which took over from the French tropical agricultural research institutes. IRHO/CIRAD has a mandate to undertake any type of study, research, surveys, and experiments on tropical oil crops, mainly oil palm, coconut (*Cocos nucifera*), groundnut (*Arachis hypogaea*), soybean (*Glycine max*), and certain others, both annual [sesame (*Sesamum indicum*) and castor-oil (*Ricinus communis*) plant] and perennial [shea nut (*Butyrospermum parkii*), jojoba (*Simmondsia chinensis*), etc.], with a view to improving their cultivation and exploitation, as well as product extraction, preparation, and processing. IRHO/CIRAD is also charged with studying possible crop outlets and conducting the necessary research to increase consumption of the crops and their by-products and derivatives.

Based on rigorous scientific research and practical application of the results obtained, IRHO/CIRAD covers the entire chain of operations from plant breeding through to product processing and utilization. Its researchers or development staff, trained in various fields (genetics, agronomy, physiology, soil sciences, entomology, statistics, technology, and chemistry), work jointly, concentrating their efforts on specific productions and programs. They work with their counterparts throughout the world on research and tropical oilcrop production, and in collaboration with specialists in various general fields. This specialized international coordination provides the scientific and economic information to give research the best chance of success.

Lastly, IRHO/CIRAD's research and development work on specific projects calls for close cooperation with professional bodies and development organizations in order to better determine development needs.

IRHO has 186 full-time staff, 81 of whom are researchers and engineers on overseas postings in 30 countries spread over all 5 continents.

IRHO's work covers the following fields of activity.

Scientific and Technical Research

Research work is concentrated on:

Production improvements.

- The quality of selected seeds or clones obtained by in vitro culture;
- Drought and disease tolerance (physiology and breeding);
- Determining the fertilizers needed and adequate levels, using leaf analysis and mineral nutrition experiments;
- Knowledge and conservation of the natural environment and crop conditions;
- Crop techniques, harvesting, and mechanization methods;
- Disease and pest control;

- Production systems adapted to various socio-economic contexts;
- Yield elaboration, modeling, and plant physiology;
- Modification of oil composition, along with studies of new species and diversification; and
- Development of new techniques and adaptation to tropical oil crops (remote sensing, cryopreservation, electrophoresis, mitochondria, etc.).

Product processing and utilization.
- Processing and extraction technology;
- Quality improvement and new uses; and
- Work on lipochemistry and biotechnology to obtain new products.

Development

Production field.
- Soil and climatological studies to determine the areas suitable for the cultivation of a given oil crop;
- Technical support and advice on setting up and monitoring plantations and programs, and specific techniques for cropping and harvesting, supplementary irrigation, and exploitation;
- Technical assistance on seed production, setting up and running seed gardens and seed services; and
- Pilot operations and development projects.

Technology.
- Feasibility studies and preliminary projects for palm and coconut oil mills, coconut and edible groundnut processing units, and groundnut seed-processing installations;
- Consultancy services on turnkey industrial projects; and
- Advice and technical support for the running of oil mills and installations (product milling, processing, and promotion).

Training.
- The training of engineers and technicians.

Information transfer.
- Publication of the review *Oléagineux*;
- User advice notes and monthly analytical documents;
- Specialized newsletters;
- Maintenance of documentary archives on tropical oil crops and access to CIRAD's computerized central data bank (CIDARC);
- Question-answer service; and
- Publication of documents.

Groundnut Research at IRHO-CIRAD

The groundnut program is one of CIRAD's 39 research programs; it is being implemented by IRHO's Annual Oil Crops Division (DOA) in conjunction with the other structures involved in the field. There are 16 staff members working on this program, 14 of whom are posted to Africa, with the remaining 2 working in France.

The Agroeconomic Context

The programs are primarily drawn up in accordance with the requirements of traditional African small holdings and their production methods, the main characteristics of which are as follows:

- Manual farming, or light animal-drawn implements;
- Low or zero-input consumption; and
- A strategy to reduce risks in groundnut-cereal-fallow rotation systems.

In this context, which determines our main field of activity, the most vulnerable points in the producer-consumer chain in the short term are:

- Seed availability for selected varieties with good germinating ability (groundnut seeds are fragile and their multiplication rate is low);
- Disease and predator incidence, in the field (leaf diseases), in stocks (insect damage), and in the final product (mycotoxins);
- Organization of product marketing and payment to the producer (guaranteed outlets, pricing, and agricultural credit policies), which govern access to inputs and technical innovation; and, in the long term,
- Fertility conservation in very fragile soils where groundnut is usually grown, as it copes relatively better than other crops.

Operating Methods

Unlike cotton (*Gossypium* spp) research in French-speaking Africa, DOA has no associated specialized structure for production development and product transformation and processing. It has therefore had to invest heavily in designing and implementing development operations combined with applied research programs; hence the highly integrated nature of our operations, which cover all stages of the producer-consumer chain from creation of sowing material right through to final product processing and export, in conjunction with our African partners and the specialized structures within IRHO, CIRAD, and ORSTOM.

Our operations take three major forms:

1. Research bases, where programs of general interest are implemented (particularly variety creation and physiology). They are located in Senegal for the dry zones and in Burkina Faso for the humid zones. A third base, in the subequatorial zone of the Congo, was closed down in 1965, but is due to be reopened in the new context of the Groundnut Network.
2. R&D oriented programs of limited duration, covering two main areas:
   - Screening of sowing material and development of cropping techniques, and
   - Supply and multiplication of foundation seeds, and setting up of seed services.

   These types of operations have been conducted in Niger, Mali, Chad, and Mozambique (lasting 4 to 10 years); others are under way in Botswana, Madagascar, and Guinea-Bissau.
3. Participation in development: the usual approach is to draw up and run pilot projects based on research results, then integrate them into national structures to which we continue to provide technical assistance. This was the case with the groundnut seed project in Senegal, which became the National Seed Service, then the Directorate for Seed Production and Quality Control, and in the edible groundnut project, integrated into regional development companies in Senegal, then into semi-public structures that thereafter provide supervision and ensure agricultural, technical, and commercial promotion of the production.

Agronomical, agroeconomic, or agroindustrial studies are also carried out within the groundnut sector at the request of the governments and organizations involved.

Scientific Partners

Our direct and permanent partners are national agricultural research institutes and the other national structures to which we provide our services, along with associated French organizations, the Institut francais de recherche scientifique pour le développement en coopération (ORSTOM) and the Institut national de la recherche agronomique (INRA). Also worthy of mention are:

- European, African, and American universities – Paris VII, physiology of drought tolerance; Dijon, cold tolerance; Florida, edible groundnut; Texas, leaf and cryptogamic diseases; University College London, leaf diseases; Ouagadougou, leaf diseases; Ceará, Brazil, drought tolerance, etc.
- Specialized organizations: the Centre technique interprofessionnel des oléagineux metropolitains (CETIOM), France; the African Groundnut Council (AGC), Nigeria; the American Peanut Research and Education Society (APRES), USA; the Natural Resources Institute (NRI), UK; the Southern African Centre for Cooperation in Agricultural Research (SACCAR), Botswana, etc.
- International Centers: close ties have been established with ICRISAT, especially at the ICRISAT Sahelian Center (Niger) and the SADCC-ICRISAT Groundnut Project at Chitedze in Malawi. Joint programs are under way in Africa and Montpellier, where crop protection studies are being carried out at the latter location involving contaminations that cannot be undertaken in the groundnut producing countries.
- The Conférence des responsables de recherche agronomique africains (CORAF), whose members are the institutions of 16 African countries. CIRAD is an associate member. Its raison d'être is to strengthen national research structures and coordinate their programs through networks; to date there are networks for groundnut, maize (*Zea mays*), rice, cotton, cassava (*Manihot esculenta*), and drought resistance. The groundnut network has a center based in Senegal, manages joint projects, circulates an information newsletter, and organizes annual thematic workshops. The CIRAD groundnut program participates in all of these activities.

Overview of Programs

Agronomy

Rotation-soil fertility studies. Successive groundnut-millet or groundnut-sorghum (*Sorghum bicolor*) cropping, which is typical of the Sudan-Sahelian Zone, provides knowledge of how soils and yields evolve depending on the rotation patterns and cropping techniques used; it is therefore possible to determine conditions for cost-effective and sustainable intensification. It became clear that organic matter availability was an essential prerequisite for maintaining a continuous cropping system (especially for cereal production) and that the systems that generate the most income, while conserving the fertility level, were those that combined continuous cropping with annual organic fertilizer applications, a slight mineral supplement, and adapted farming operations accessible to African small holders. These trials (the oldest was set up in 1960) make it possible to measure the effects of rotations and techniques on several parameters (soil, plants, parasite pressure, and productivity) under very stable conditions representative of the real environment.

Mineral Nutrition and Fertilization Study

The leaf analysis technique, adapted to groundnut, is used in all the research programs monitored by IRHO. The element contents, determined by leaf sample analysis, provide useful indications on plant mineral nutrition. Critical levels (deficiency thresholds) have been determined for N, P, K, Ca, Mg, and S, along with their interactions, and a standardized sampling, analysis, and interpretation method has been developed. It can be used to monitor plant nutrition in relation to the treatments studied (rotations, fertilizers, soil tillage, varieties, etc.) and to effectively reduce the impact of any deficits on production.

Plant fertilizer requirements vary according to climatic conditions, the acceleration of rotations, and the varieties grown. The most effective rates and forms and the area of application for each formula vary, depending on the natural environment and the policies followed in the different producer countries. It is necessary to develop low-cost fertilizer formulas (combinations of mineral fertilizers – organic restitution) and make the most of local resources (by the use of natural raw phosphates or by transformation into basic or annual fertilizer). This work is under way in Senegal, Burkina Faso, and Botswana.

Husbandry and production methods. Optimization of inputs, especially fertilizer, can only be ensured if basic cropping techniques are perfected and mastered. This problem, which is too often considered resolved or a thing of the past, still exists in all producer countries. Climatic changes, modifications to the variety range, and increasing socioeconomic constraints (pricing, credit, and input distribution policies) lead us to update our knowledge and our operating strategy, moving towards greater flexibility; 'soft' technologies derived from traditional methods (intercropping and input savings) and intensive production methods (irrigation and mechanization) intended primarily for high-income crops, seeds, and edible groundnut are developed at the same time.

Breeding

Basic research (sowing material creation and development of physiological tests and screening techniques for groundnut) is carried out in Senegal for dry zones, where the main constraint is drought, and in Burkina Faso for humid zones, where the main constraint is diseases. A more limited variety improvement program based on local and introduced material is being conducted in the multidisciplinary groundnut programs located in Botswana, Guinea-Bissau, and Madagascar. All these projects produce and multiply groundnut foundation seed in conjunction with the local seed services to whom IRHO provides technical assistance.

Productivity improvement. This topic covers agronomical capabilities and the quality of the products obtained. Breeding criteria are taken into account: yield (with its main components being pods, haulm, emergence, and shelling); ecological adaptation (cycle length, dormancy, and drought and disease tolerance); adaptation to cropping techniques (response to fertilizers and mechanized farming); and product quality (oil content, amino acid composition, hygiene, and organoleptic qualities).

Drought tolerance. This dual topic (physiology-breeding) sets out to develop tolerant varieties through selection based on physiological criteria:

- Short-cycle varieties with dormant seeds (variety 73-30 extended in Senegal); and
- Variable-cycle varieties capable of tolerating periods of water stress during vegetative development. Selection is carried out from a basic population created by intercrossing eight varieties chosen for their complementary qualities. Alternation of generations between Senegal and Botswana makes it possible to speed up the program and subject sowing material, once it is grown in the field, to different drought conditions.

Tolerance to leaf diseases. Rosette-resistant material has been obtained and very widely distributed. The aim of the programs under way in Burkina Faso is to develop varieties that are resistant to both rosette and to the cryptogamic diseases that are often rife at the same time as rosette: rust (*Puccinia arachidis*) and cercospora leaf spot diseases. Artificial inoculation tests have been developed and hybrid progenies are being screened in Burkina Faso, along with families currently undergoing selection for other research topics and intended for zones exposed to these diseases.

Tolerance to *Aspergillus flavus*. The differences in the degree of contamination of seeds by *A. flavus* in the soil prior to harvesting has been shown. Crosses are currently being carried out between extended varieties and parents with known resistance, and the progenies are being screened in artificial inoculation tests.

Edible groundnut. Selection of edible groundnut that can be marketed in shell or seed form is currently under way in Senegal and Burkina Faso. Satisfactory varieties have been obtained and the current programs are directed towards producing higher-yielding varieties resistant to diseases, and to improving seed shape and size. These programs are of interest to numerous producer countries to meet the requirements of the domestic market and for export on the highly profitable international market (twice as profitable, on average, as oil mill groundnut in the case of variety GH 119-20 extended in Senegal).

Crop Protection

Phytosanitary problems with groundnut in Africa are becoming more acute as cropping rotations become shorter, double annual cropping becomes widespread, and international seed exchanges develop. Research into these problems has been done with regard to cropping methods, variety improvement, and chemical control.

Protection from diseases and pests on emergence. Many fungi are responsible for emergence losses that may reach 50%. Seeds therefore need protection and effective formulas have been developed and made widely available. As fungal flora and pest action vary in time and space, and sowing material susceptibility is different, these studies need to be continued in different situations, and the repulsive effect on termite and millipede attacks needs to be assessed.

Millipede control. Millipedes attack plants and young pods as they form. Poisoned baits have been developed and used in Senegal. Biological and epidemiological research is being conducted with ORSTOM and the Natural History Museum in Paris. This work should be continued, determining the most vulnerable stages of the julid's biological cycle and developing new products through experimentation. Biological control is being considered.

Aflatoxin control. Studies have been carried out at all stages of the groundnut producer-consumer chain – genetics, agronomy (prevention of contamination in the field), and technology (elimination of contaminated pods and seeds and detoxification). An artificial inoculation test has been developed to determine a reference susceptibility scale. An additional test, based on seed coat permeability, is being investigated and the correlation with actual contamination in the field is being measured. Field prevention techniques (and checking techniques at the time of harvest) have been developed (threshing before drying, rapid drying, and purchasing based on quality). Current studies are concentrating on assessing and controlling preharvest contamination in various ecological zones, and on determining critical susceptibility phases.

Nematode control. The results obtained led to the implementation of a nematode treatment project in North-central Senegal (5600 ha in 1990). The technique has now been perfected, but trials are under way to reduce doses, test other products, and determine the optimum application date. Much still remains to be done in the field of adaptive agricultural research, particularly to determine the sowing density and fertilizer level that will best optimize the treatment and conserve soil fertility with substantially increased yields.

Leaf disease control. The impact of rust, combined with that of cercospora leaf spot diseases, is increasing in West Africa. Effective treatments exist, but they are too costly in extensive crops. The research under way is concentrating on selection tests on cross progenies based on resistance to rust both in the laboratory and in the field. These programs are backed up by contamination trials that cannot be conducted in producer countries and are therefore carried out in Montpellier (IRHO Phytopathology Division) with infesting strains from various places inoculated into different varieties ranging from the most tolerant to the most susceptible. IRHO is working on this topic in conjunction with ICRISAT and University College London.

Technology

The groundnut technology program is primarily located in Senegal and consists of two parts: one is devoted to technology proper and the other covers the conditions under which aflatoxins appear in groundnut, along with control methods.

Improvement of technological and seed qualities in groundnut. The criteria for assessing the technological quality of edible groundnut have been defined and assessment tests and analytical methods have been developed. Several varieties have been chosen and proposed for dissemination. The effects of various agronomical treatments have been measured and corresponding research recommendations are made and adapted to the destination of the product (effect of Ca on exportable seed yields and germination capacity, effect of B on germinating capacity, effect of growth regulators on seed value, etc.).

Study of shelled groundnut conservation and storage procedures. A method of insect eradication in stocks has been developed (fumigation and dusting). Refrigerated storage has been used for a long time, but the gradual return of the seed stock to ambient temperature upon removal from storage requires careful attention. Packaging in sealed packs in a modified atmosphere (nitrogen compensated vacuum) gives the best results and ensures good preservation conditions at the lowest price. The technique should be further improved with a view to using it on the seed capital and possibly on cereal stocks.

Control of *Aspergillus flavus* contamination in groundnut. This aspect of the program is conducted in part with breeding operations (screening of hybrid progenies); it also covers industrial processes for eliminating contaminated pods and seeds, selective skinning with hydrogen peroxide, and chemical detoxification of press-cakes.

Improvement of industrial seed processing. Production of top quality seeds for sowing or for export onto the confectionery groundnut market is examined at several stages of the industrial process: shelling, electronic sorting, skinning, and production of ready-to-use seeds. The entire sequence of operations can now be mechanized (shelling, sorting, coating, and packaging). Moving from the experimental stage to industrial pilot-plant level, especially with regard to coating seed with fungicides, remains problematical (average coating rate, fungicide solution distribution, and adhesion).

These processes are extremely important in Senegal, since the reduction in the seed capital distributed by the state means that more efforts have to be made in maintaining and improving the seed quality. At the same time, greater attention needs to be paid to problems that occur when small-holders produce and store seed.

Development Support

Groundnut seed multiplication in Senegal. Up to 1990, the Institut sénégalais de recherche agricole (ISRA) and IRHO provided direct technical support to the Directorate for Seed Production and Quality Control in Senegal, both for programming and checking production and for seed technology, storage and packaging. The variety range has been completely modified over the last decade, which has been characterized by severe droughts, and production potential has always been maintained. The 'New Agricultural Policy' established by Senegal in 1985 is based on small-holder responsibility, who have to purchase their seed in cash. Eventually, small-holder seed stocks will only be renewed every 3 years. This means that a good quality emergency stock will have to be maintained and farmers will need assistance to produce and store their own personal seed stocks.

Edible groundnut operation in Senegal. Under the New Agricultural Policy, coordination of edible groundnut production has been entrusted to a semi-public company under the technical responsibility of an IRHO agent. An integrated system ensures input supplies and utilization: organization of credit for the cropping year in question; farmer selection and training; crop monitoring; harvest purchasing; credit recovery; transport organization and delivery to processing units; and seed production, packaging, and storage. The company has asked IRHO to carry out studies for the installation of a production processing unit with a capacity of 25 000 t, extendable to 50 000 t, including a salted-roasted groundnut packaging unit and a peanut butter manufacturing unit, whose basic techniques are directly derived from research results.

Nematode control in Senegal. Nematodes damage groundnut and rotation crops, millet and cowpea (*Vigna unguiculata*). Spectacular results have been obtained with nematicide treatments in the northern half of the groundnut basin, with regard to pods, haulm, and seeds. A control project was launched in 1984 with a view to promoting 'denematization' under the best possible conditions in the field in the Thiès and Diourbel zones, with possible extension to the North and South. An IRHO researcher had technical responsibility for the operation up to 1990. The effects and after-effects obtained on thousands of hectares were very substantial: an additional 500 kg of pods ha^{-1} in 1985, 710 kg in 1986, and 790 kg in 1987 as a direct effect, with 250 kg ha^{-1} and 350 kg ha^{-1} for cereals in the second year and 400 kg ha^{-1} with groundnut in the third year. More still needs to be done to acquire better knowledge of nematode biology and epidemiology, to reduce treatment costs, adjust cropping techniques (sowing density, fertilization), and develop large-scale treatment methods.

Seed plan implementation. IRHO operations in Guinea-Bissau, Botswana, and Madagascar, based on references acquired in Senegal and Burkina Faso, take the form of combined research-seed production operations. The latter aspect would seem to be the main limiting factor in extending and improving the crop. First of all, the varieties obtained from selection programs are multiplied directly on a farm or experimental station; they are subsequently multiplied by contract farmers under the direct supervision of the IRHO agent in charge (Guinea-Bissau) or via the Seed Service to which IRHO lends its technical support (Botswana). Similar operations have been carried out in Chad, Niger, and Mozambique.

The interaction between these operations and research programs is particularly rewarding; it enables researchers to adapt specifically to the needs and difficulties of the rural world, making the program coherent, realistic, and commodity-oriented.

Discussion

M.A. Bellamy: Is the proposed FAO project to set up a Centre for Dissemination of Groundnut Information designed to complement existing activities, such as those of ICRISAT?
N. Chamchalow: The project proposal is being developed in consultation with a number of centers, including ICRISAT.

O. Badiane: How is it that fertilizer recommendations and varieties in Senegal have not changed after 30 years?
R. Schilling: Fertilizer recommendations have changed in Senegal, in particular by incorporation of more potash in areas where intensive cropping is practiced. The example of farmer recommendations still applied in many cases, was given to illustrate the good transfer of research results for development. These recommendations governed the fertilizer formulations and distribution in the country. Lately fertilizer use has declined in the country due to reduction in credit facilities and subsidies. Similarly, new cultivars have also been developed to suit changing agroecological conditions.

M.B. Syamasonta: Is there any prescribed format to request bilateral funding for groundnut research from ODA?
J.C. Davies: There is no set format for request of bilateral funds. Allocations to natural resources research are made on a demand-led basis. It is important for researchers to press for money within the priorities of government plans for the natural resources sector. Presently we, in the UK, are concerned about the declining funds available for natural resources research because many aid recipient countries allocate low priority to it. Therefore, researchers should push for priority to be given to natural resources research in view of its importance to most developing countries.

Special Topics

From *Ynchic* (*Maní*) to Peanut Butter and Beyond: Appropriate Information Transfer for the Year 2000

M.A. Bellamy[1]

Abstract

*After a brief historical introduction, the paper identifies users of scientific and agricultural information and their needs. It takes as an example the various stages in groundnut (*Arachis hypogaea*) production, in which access to accurate, timely, appropriate packaged information plays, or should play, an important part. The role played by various means of information transfer, including new information technology, and some of the activities in this area at the national and international level are outlined as a basis for fuller discussion in open forum. The emphasis is on information support for research, but of particular concern is whether the information needs of a major target group for the rest of this century—small farmers—can be answered directly or indirectly by the mechanisms and sources currently or potentially available. In this context some of the problems associated with information transfer in the research-extension-farmer continuum are mentioned, drawing on the vast and sometimes conflicting body of literature about, and practical experiences of, these linkages.*

Résumé

Du* Ynchic (manf) *au beurre d'arachide et au delà—transfert d'information appropriée pour l'an 2000: *Après un bref exposé historique cette communication identifie les usagers d'information scientifique et agricole et leurs besoins. Elle prend pour exemples les diverses étapes de la production d'arachide (*Arachis hypogaea*) dans lesquelles l'accès à une information précise, opportune, appropriée et bien présentée joue ou devrait jouer un rôle important. Le rôle joué par les différentes voies d'information, y compris les nouvelles technologies d'information ainsi que certaines des activités dans ce domaine au niveau national et international sont décrits, comme base d'une discussion plus poussée par une tribune ouverte. L'accent est sur l'appui que l'information peut donner à la recherche et surtout si les besoins d'information d'un grand groupe cible pour le reste de ce siècle—les petits cultivateurs—peuvent être satisfaits directement ou indirectement par les mécanismes et les sources déjà disponibles ou qui pourraient le devenir. Dans ce contexte, certains des problèmes associés à un transfert d'information dans le continuum recherche-vulgarisation-exploitant, sont mentionnés, en puisant dans les vastes ressources publiées et parfois contradictoires et dans les expériences pratiques de ces liens.*

It is quite daunting to realize that the groundnut (*Arachis hypogaea*) has probably been known as a food crop, and information about it transferred, for as long as four thousand years (Hammons 1973; Purseglove 1968; Weiss 1983). The archaeological evidence from South and Central America indicates its being known and widespread in pre-Columbian times, used as a food, and clearly illustrated on pottery discovered in Peru and elsewhere. Its exact origin was not recorded by its Amerindian domesticators, although some scholars believe the common denominator may have been the Arawak people.

1. Head, Division of Natural Resources, Forestry, and Economics, Information Services, CAB International, Wallingford, Oxon OX10 8DE, UK.

Bellamy, M.A. 1992. From *ynchic* (*manf*) to peanut butter and beyond: appropriate information transfer for the year 2000. Pages 225–231 *in* Groundnut – a global perspective: proceedings of an international workshop, 25–29 Nov 1991, ICRISAT Center, India (Nigam, S.N., ed.). Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

We can probably only speculate as to how information transfer was effected among these early growers, but somehow information about breeding, selection, sowing, harvesting, storage, and processing must have been communicated by farmers themselves, between peoples over vast geographical distances, and between cultures. The evidence strongly supports the view, widely held today, of farmers themselves as custodians and disseminators of information/knowledge, surely a very early example of indigenous knowledge systems.

Communication about the groundnut in a form that we recognize, the written word and illustrations, dates back only to the early 16th century, the era during which the crop spread to Africa and Europe. There is no record of groundnuts in the writings of ancient Greek, Latin, Arab, or Sanskrit scholars, and the earliest references in China are considerably subsequent to the discovery and conquest of America. A chronological table in Hammons (1973) shows the documentation of the groundnut in early post-Columbian historical records (missionaries, scientists, soldiers, and administrators). However, the profusion of natural histories in the 17th century contained few accurate descriptions and drawings, as would be acceptable to today's botanists, and some misconceptions about the plant survived until the 20th century. Information transfer was thus both slow and sometimes inaccurate.

To give a historical perspective, scientific breeding of the groundnut in the modern sense, for commercial purposes, dates from the late 19th century, processing as oil from the early 1800s, and the ubiquitous peanut butter from a patent of 1897. Thus, the commercial and industrial use of the groundnut as we know it will be less than 200 years old by the year 2000, but in a vastly different environment from that of its original cultivators.

Access to Information

Access to information and the means to communicate it have come a long way since the pre-Columbian farmer, or indeed the 16th century botanist. And in the last 10 years the technology available to process and transfer information has developed dramatically. However, as this section indicates, the type of information and the way it is transferred depends very much on the nature and demands of the users and their particular needs. The next few sections outline some of the general features of information needs and use, before focusing particularly on information transfer to and among the research community.

Value of Information

Purseglove (1968) observed that in 1938, as an up-country agricultural officer in Uganda, he had no reference works but his own library and lecture notes from his course at the Imperial College of Tropical Agriculture in Trinidad. This scientific isolation is regrettably still experienced today by some scientists in developing countries; the information is known to be available, but the means and resources to gain access to it may not.

It is absolutely essential for a viable, relevant agricultural research system that adequate facilities and resources are provided to enable researchers, policymakers, and all others concerned with identifying research needs, to carry out research and disseminate its results. Without information, time, money, and manpower are wasted and research is duplicated. It can be argued that access to and provision of information is the single most important prerequisite for an efficient, productive, and relevant research system (ISNAR 1990).

ICRISAT's current strategy echoes these views in giving increased priority to information (ICRISAT 1991). In the past, information was accorded less priority than research; in 1991 it is regarded as an integral part of ICRISAT's research work. The aim is to coordinate information activities, share resources, engage in joint projects, and avoid duplication, assist national programs through technical advice and training, assist in identifying and reaching end users for services, products, and technologies, and assist in upgrading the skills of national information personnel. This view has a bearing on the rest of the discussion in this paper.

Users and needs

Clearly, the pre-Columbian cultivators and their households needed and exchanged information, but it appears their endeavors were largely for subsistence needs. The range of users who need information today regard the groundnut as much more than a subsistence crop, although its value as food, in both natural and processed form, is of course still widely recognized. If we look at some of its uses today, we can see the wide range of information needs to be answered. Production is still largely for oil, but some of the derived products and uses indicate the range of potential needs and users of information: salad oil, margarine and cooking oil, soap, pharmaceuticals, vegetable ghee, food, flour/meal, peanut butter, seeds; and the byproducts are used as fertilizers, feeds, and fuel [listed in Duke (1981) and discussed in more detail in Woodruff (1983)].

Generally, users of information can be classified into four groups (after Metcalfe 1984):

Group 1	Research scientists Specialist advisers General advisers Educated growers Other growers
Group 2	Politicians Administrators Planners
Group 3	Manufacturers/Processors Bankers Salesmen Traders Journalists/Media
Group 4	Academics Teachers Students

Group 1 comprises those intimately concerned with the detailed technology of production; Group 2 is broadly concerned with making and implementing policy; Group 3 brings together those in the service area; and Group 4 identifies the academic community, the teaching, and the taught. To these can be added such diverse groups as consultants, who may serve the needs of any other group, and others with national and international interests, such as aid donors, International Agricultural Research Centers (IARCs), and Non-Government Organizations (NGOs). The common denominator is the need for information; the difference lies in the level to which and in what form the information needs to be transferred.

What information is needed?

Information needs related to groundnuts, and indeed any other crop, follow these stages:

- Genetic material;
- Sowing;
- Agronomic/cultivation practices;
- Inputs - fertilizers, weeding, pest and disease management, irrigation, and labor;
- Harvesting;
- Postharvest losses;
- Marketing and distribution;
- Prices, trade, and markets;
- Processing, including food technology, biochemistry, and nutrition;
- Consumers;
- Dietary considerations;
- New uses; and
- Use of waste products.

To this list should be added information about complementary or competitive crops, the general economic and agricultural situation, and statistics.

Matching users and needs

The assortment of users identified earlier basically needs three types of information, which may be related to any of the stages described above: detailed scientific data, summary data, and explicit recommendations. For example, scientists concerned with breeding new varieties will want all the information they can get on gene pools, breeding techniques, varieties developed elsewhere, and so on. The agronomist will want to know about fertilizer reactions on different soil types, benefits of irrigation, pest and disease control, and different cultivation practices. Both these groups are dealing with largely undigested information. At the policy level, the Permanent Secretary in a Ministry of Agriculture may want to know what resources are needed to increase production, suitable regions, and limiting factors. To answer this requires study, analysis, and evaluation. Finally, the extension worker, dealing directly with the farmer, may need to answer a very simple question, such as "when is the best time to sow?" The answer may be the result of years of experience or scientific research.

Pattern of information transfer

Information transfer in agriculture involves activities at many different levels, and also flows in both directions between source and recipient.

Before being transferred, the information has to be gathered and consolidated; this process involves a number of steps:

- Collecting data;
- Evaluating findings;
- Compressing the information;
- Making sure the information is relevant;
- Preparing it in a form suitable for the particular group of users; and
- Producing reliable concise, new bodies of knowledge.

The discussion below is particularly concerned with how researchers acquire and transfer knowledge. but some of the principles and methods apply to other groups as well.

Means of transferring scientific and technical information

There are various ways and means by which information can be obtained, and which are often interdependent:

- Contacts: 'invisible college', workshops, and conferences;
- Network: formalizes the 'invisible college';
- Professional societies: e.g., American Peanut Research and Education Society;
- Newsletters: e.g., *International Arachis Newsletter*, *Groundnut News*;
- Printed publications: books, journals, monographs, and conference proceedings;
- Research digests: e.g., Aflatoxin database;
- Databases: derived products, in printed and electronic form, e.g., CD-ROM;
- Databanks: statistics and plant germplasm collections; and
- Other information technology: Geographic Information Systems (GIS), satellite imagery, expert systems, and maps.

Contacts. Those people who go to conferences already know others there: fellow students, present or former colleagues, and authors of familiar reference material. This informal, 'invisible college' builds up during a career or lifetime, so that each of us has such a group we know and trust as sources of information and support. This is perhaps the oldest method of information transfer, facilitated greatly in the last few years by modern telecommunications, especially the fax machine.

Networking. Formal and informal networks of researchers worldwide greatly facilitate contact and strengthen the 'invisible colleges'. ICRISAT itself has crop networks, which it regards as major channels for transferring technology, and these operate in Asia, Africa, and Latin America. The recent strategy document clearly attaches great importance to these as means of transferring technology and, by implication, information. Four major types of networks in international agricultural research are recognized, and a database provided, in a recent Consultative Group on International Agricultural Research (CGIAR) Study Paper (Plucknett et al. 1990). The whole question of agricultural research networks as development trends has been amply debated recently by Faris (1991); this is being described elsewhere in these Proceedings (pp. 355-363).

Professional societies. These bring together professional scientists engaged in all branches and sectors of an industry – a significant example is the American Peanut Research and Education Association, whose past activities have included publishing 'Peanuts – culture and uses' in 1973 and 'Peanut science and technology' in 1982.

Newsletters. These are often the formal means of communication between both contacts and networks. The prime example before us is the *International Arachis Newsletter*, which links workers throughout the world who are interested in the research and development of groundnut and its wild relatives. The last issue (No. 9, May 1991) attests to its rapid growth, reporting a mailing list of 204 institutional heads in 52 countries, 678 libraries in 79 countries, and 901 individual scientists in 73 countries. Its documentation of both news and current research really does keep scientists both up-to-date and in touch with one another. Within India, *Groundnut News* is in its third year; there must be many such examples worldwide.

Printed publications. Original published documents – books, monographs, journal articles, and conference proceedings – continue to be the primary source of literature, but may not be accessible in this form outside developed countries. Some of the seminal reference works on groundnut, for example, may not be easily available and are expensive to purchase, although others are available through book programs, donations, etc. Fortunately the printed publications of most of the CGIAR institutions, such as those from ICRISAT, are easily available.

Research digests. The aflatoxin database recently developed by ICRISAT is a good example of this.

Databases. Several international, regional, and national organizations are engaged in documenting the world's scientific and technical literature. The criteria for selection, and methods of presentation and distribution, vary according to mandate, resources, and clientèle, but a major goal is common to all – to disseminate accurate, reliable, timely information in appropriate forms to those who need it. Most bibliographic databases began with printed products, such as abstract journals and bibliographies. CAB International, the Food and Agriculture Organization of the United Nations (FAO), USDA's National Agricultural Library (NAL), the Royal Tropical Institute (KIT), the International Food Information Service (IFIS), and the Centre de coopération internationale en recherche agronomique pour le développement (CIRAD) are all examples of organizations producing these on the international scale. However, computers and electronic forms of information storage and retrieval have revolutionized both the methods by which databases are produced, and the products that can be derived from them. The late 1980s saw the development of the CD-ROM (Compact Disc-Read Only Memory), a medium where each disc stores the equivalent of 220 000 pages of A4, or 1500 floppy discs. In terms of agricultural databases, one CD-ROM disc can store 350 000 bibliographic records, including abstracts and indexes, in a form which is both user-friendly and independent of telecommunications. In 1991 at least six directly relevant discs are available to agricultural researchers: NAL's AGRICOLA, FAO's AGRIS, CIRAD's SESAME, KIT's TROPAG, IFIS' FSTA, AND CAB ABSTRACTS.

A more modest way of downloading data from a computerized database is by a regular profile tailored to meet specific needs. One such product of particular relevance to groundnut researchers is *Groundnuts*, a quarterly bibliography published by CAB International in association with ICRISAT and distributed worldwide through sponsorship from the International Development Research Centre (IDRC). More than 3000 abstracts, from the whole range of subjects covered by the CAB ABSTRACTS database, will have been published in *Groundnuts* by the end of 1991.

We shall be hearing more later about ICRISAT's Semi-Arid Tropical Crops Information Service (SATCRIS), so I shall not attempt to describe it here (see also Haravu et al. 1990).

Databanks. Modern information systems greatly simplify the keeping of extensive detailed records of all kinds, relating to all stages of production and processing. The painstaking work of taxonomists, statisticians, and others can now be committed to electronic form, kept up-to-date, and made available worldwide. For example, plant germplasm conservation is a major concern of IBPGR and others; two recent papers indicate the importance of documenting, as well as conserving and holding these genetic resources (Williams 1989; Mowder and Stoner 1989). The United States Department of Agriculture's Agricultural Research Service has developed a centralized computer database to provide and store detailed information on collection, maintenance, distribution and use of plant germplasm held by the U.S. National Plant Germplasm System. The resulting Germplasm Resources Information Network (GRIN) service is a central repository for genetic resources information. Other such databanks exist in Japan and elsewhere, and are underway in India, Canada, Mexico, and Australia. ICRISAT, through its newsletter and by other means, is collecting data on groundnut cultivars released in various parts of the world; presumably these returns will be processed into electronic format.

Other examples and needs will no doubt emerge in discussion. We look forward, for example, to hearing more about ICRISAT's own work in the area of databanks.

Other information technology. Some new information technology has enormous potential. ICRISAT itself envisages a research environment by the year 2000 in which exchange of information by computer, geographic information systems, and satellite imagery will be commonplace (ICRISAT 1991). To these should be added databases and computerized distribution maps on major pests and diseases, and expert systems for their diagnosis, such as those being developed at ICRISAT, and multimedia and full text CD-ROMs comprising elements of the information formats already described. By the end of 1991 a CD-ROM of the full text of CGIAR publications will be available; Cornell University is developing core reference lists of books and journals in each major discipline of agriculture of some literature relevant to developing countries, with a view to producing full-text CD-ROMs for each. And there is potential for multimedia CD-ROMs comprising diagnostic expert systems (e.g., for a pest), background bibliographic data, distribution maps, and full text. Could we imagine such media developing for those two scourges of the groundnut, aflatoxin and groundnut rosette virus?

Information Transfer and the Small Farmer

Access by the scientist to the plethora of information available worldwide does not necessarily benefit the producer; nor does it guarantee that the right messages are given or received in either direction or by intermediaries. ICRISAT quite rightly gives priority in its current strategy document to the small-scale farmer in the semi-arid tropics as its target group. All of us with access to information and resources should be concerned with means of ensuring the right linkages and the right flows of information.

Increased groundnut production may be a goal to meet all kinds of consumer needs and national self sufficiency goals, but it will only become a reality if producers can see the real benefits to themselves. And, so long as the effort is concentrated on small producers, there should be no repeat of that great agricultural fiasco, the ill-fated Groundnut Scheme, implemented in Tanzania in the late 1940s, the failure of which can surely be attributed partly to lack of essential information-gathering and the attempt to produce what is essentially a small-farm crop using prairie methods in the wrong conditions.

Before discussing ways and means, we should be aware of the vast (often controversial) literature documenting both theory and practice on technology transfer, research-extension-farmer linkages, the messages of which are equally valid to this discussion. The debate can almost be said to have gone full circle; much of the current emphasis seems to be on awareness of indigenous knowledge systems, and the social, economic, and cultural background within which the farmer operates and is prepared to absorb new knowledge (Beal et al. 1986; Röling 1988). The evolution from training and visit, through farming systems research, to participatory research, has been a major feature of the past decade, formalized most recently in documents emanating from the International Service for National Agricultural Research (ISNAR) (Seegers and Kaimowitz 1989), the Overseas Development Institute (ODI), and those such as Biggs (1990), Farrington and Martin (1988), and others. Thimm's view of the small-scale farm as "the world's largest research laboratory" (Thimm 1989) is borne out by other work, notably that of the Centro Internacional de la Papa (CIP) among Andean potato producers in Peru, which illustrates the potential for conflict between local knowledge systems and scientific plant breeding. Work in Thailand, Bangladesh, India, the Philippines, and the Caribbean, much of which is documented in Amanor's bibliography for ODI on participatory research, gives some clues as to how the linkages might work more effectively in practice (Amanor 1990).

Extension's Role

Extension is often portrayed as the weak link between research and the farmer; do we want it strengthened or changed, or do we see other, newer linkages bypassing extension? Can information technology and other modern media make the linkages direct, or is extension itself in a process of change? These are the sorts of questions to which we need to find answers if all the resources being expended on modernizing research and information technology are really to benefit the small farmer.

In conclusion, we seem to have access to the tools and to the raw data; our responsibility is to ensure that the media of transfer, and what is transferred, are appropriate to the needs of the end users of that information. We owe it to the four thousand years of history of groundnut production to improve the lot of today's successor to those pre-Columbian Amerindian cultivators.

References

Amanor, K. 1990. Analytical abstracts on farmer participatory research. Occasional Paper, Agricultural Administration Unit no. 10. London, UK: Overseas Development Institute.

APREA (American Peanut Research and Education Association). 1973. Peanuts – culture and uses. Stillwater, Oklahoma, USA: APREA.

Beal, G.M., Dissanayake, W., and **Konoshima, S. (eds.)** 1986. Knowledge generation, exchange, and utilization. Boulder, Colorado, USA: Westview Press.

Biggs, S.D. 1990. A multiple source of innovation model of agricultural research and technology promotion. World Development 18(11):1481–1499.

Duke, J.A. 1981. Handbook of legumes of world economic importance. New York, USA: Plenum Press.

Faris, D.G. 1991. Agricultural research networks as development tools: views of a network coordinator. Ottawa, Canada: International Development Research Centre, and Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Farrington, J., and **Martin, A.M.** 1988. Farmer participatory research: a review of concepts and recent practices. Occasional Paper no. 9. London, UK: Overseas Development Institute.

Hammons, R.O. 1973. Early history and origin of the peanut. Pages 17–45 *in* Peanuts – culture and uses. Stillwater, Oklahoma, USA: American Peanut Research and Education Association.

Haravu, L.J., Sinha, P.K., Prasannalakshmi, S., Jotwani, D., and **Naidu, R.G.** 1990. AGRIS Level II and the information services of specialized information analysis centers: the case of SATCRIS and its SDI services. Quarterly Journal of the International Association of Agricultural Librarians and Documentalists 35(1):11–18.

ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1991. Pathways to progress in the semi-arid tropics: ICRISAT's strategic plan for the nineties. Patancheru, A.P. 502 324, India: ICRISAT.

ISNAR (International Service for National Agricultural Research). 1990. Page 66 *in* Review of the Ghana agricultural research system. Volume 2. Annexes. The Hague, Netherlands: ISNAR.

Metcalfe, J.R. 1984. Secondary services for developing countries. Aslib Proceedings 36(7–8):299–307.

Mowder, J.D., and **Stoner, A.K.** 1989. Plant germplasm information systems. Pages 419–426 *in* Biotic diversity and germplasm preservation, global imperatives (Knutson, L., and Stoner, A.K., eds.). Beltsville Symposia in Agricultural Research no. 13. Dordrecht, Netherlands: Kluwer Academic Publishers.

Plucknett, D.L., Smith, N.J.H., and **Ozgediz, S.** 1990. International agricultural research: a database of networks. Study Paper no. 26. Washington, D.C., USA: Consultative Group on International Agricultural Research.

Purseglove, J.W. 1968. Tropical crops. Dicotyledons 1. London, UK: Longmans.

Röling, N. 1988. Extension science. Information systems in agricultural development. Cambridge, UK: Cambridge University Press.

Seegers, S., and **Kaimowitz, D.** 1989. Relations between agricultural researchers and extension workers: the survey evidence. The Hague, Netherlands: International Service for National Agricultural Research.

Thimm, H.U. 1989. Wissenstransfer in die baüerliche Landwirtschaft. (In De.) Entwicklung und Läendlicher Raum 23(1):8–11.

Weiss, E.A. 1983. Groundnut. Pages 100–160 *in* Oilseed crops. Tropical Agriculture Series. London, UK: Longman.

Williams, J.T. 1989. Plant germplasm preservation: a global perspective. Pages 81–96 *in* Biotic diversity and germplasm preservation, global imperatives (Knutson, L., and Stoner, A.K., eds.). Beltsville Symposia in Agricultural Research no. 13. Dordrecht, Netherlands: Kluwer Academic Publishers.

Woodruff, J.G. (ed.) 1983. Peanuts: production, processing, products. 3rd edn. Westport, Connecticut, USA: AVI Publishing Co.

The Semi-Arid Tropical Crops Information Service (SATCRIS): Information Products and Services on Groundnut

P.K. Sinha and L.J. Haravu[1]

Abstract

*The history of the Semi-Arid Tropical Crops Information Service (SATCRIS) project, its broad objectives, and the beneficiaries of its services are described. SATCRIS builds its database by drawing information not only from agricultural databases but also from food science and biological science databases. The plan for the building of a time-series database on crops mandated to ICRISAT is indicated. SATCRIS operates an automated Selective Dissemination of Information (SDI), and conducts information searches, contributes to specialist abstracts, and conducts information analysis. Plans to build a prototype expert advisory system on groundnut (*Arachis hypogaea*) diseases identification and control, and the objectives of such a system are introduced. SATCRIS has created a specialized database on the groundnut aflatoxin problem and plans to sensitize information users in Africa to its resources and services through participation in regional workshops.*

Résumé

Le service d'information sur les cultures des zones tropicales semi-arides (SATCRIS)—produits et services de l'information sur l'arachide: *L'histoire du projet SATCRIS, avec ses principaux grands objectifs et les usagers de ses services sont décrits. Le SATCRIS développe sa banque de données en puisant dans les informations fournies non seulement par les banques de données agricoles mais aussi dans les domaines de la science alimentaire et de la biologie. Le plan de construction d'une banque de données numérique à série dans le temps sur les cultures placées sous le mandat de l'ICRISAT est indiqué. Le SATCRIS opère une diffusion sélective automatisée de l'information (SDI) et entreprend des recherches d'information, contribue à des résumés spécialisés et effectue des analyses d'information. Il est prévu de construire un système expert prototype sur l'identification des maladies de l'arachide (*Arachis hypogaea*), et leur maîtrise ainsi que les objectifs d'un tel système sont présentés. Le SATCRIS a créé une banque de données spécialisées sur le problème de l'aflatoxine de l'arachide et prévoit de sensibiliser les usagers d'information en Afrique sur ses ressources et ses services grâce à la participation à des ateliers régionaux.*

The importance of information in research and developmental activities cannot be over emphasized. ICRISAT, since its inception, has endeavored to enhance its information resources and information handling capabilities not just to keep its scientists abreast of the latest developments in their fields of interest but also to satisfy information requirements of many others who are working on its mandate crops in areas where information resources are either nonexistent or meager. ICRISAT established a specialized information center, the Sorghum and Millets Information Center (SMIC), in 1976 as a part of its Library and Docu-

1. Senior Documentation Officer and Manager, Library and Documentation Services, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, A.P. 502 324, India.

ICRISAT Conference Paper no. CP 804.

Sinha, P.K., and Haravu, L.J. 1992. The Semi-Arid Tropical Crops Information Service (SATCRIS): information products and services on groundnut. Pages 233–238 *in* Groundnut – a global perspective: proceedings of an international workshop, 25–29 Nov 1991, ICRISAT Center, India (Nigam, S.N., ed.). Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

mentation Services to collect, collate, and disseminate information on sorghum and millets. The financial support to this project was partially provided by the International Development Research Centre (IDRC), Canada. Information products and services of SMIC included comprehensive bibliographies, Selective Dissemination of Information (SDI) service, literature search service, information analysis service, and document delivery service. It also published the *SMIC Newsletter* in English and French to provide current information to researchers. A worldwide directory of sorghum and millets research workers was compiled and distributed.

SMIC was replaced by a new project, the Semi-Arid Tropical Crops Information Service (SATCRIS), in November 1986 to expand information resources, products, and services of SMIC to cover all five crops of ICRISAT's mandate. The financial support to this project was provided in part by IDRC. SATCRIS laid emphasis on the exploitation of machine-readable products of global database producers such as the CAB International (CABI) and the Food and Agriculture Organization of the United Nations (FAO) to build a comprehensive inhouse database and to provide information services. An important goal of SATCRIS was to strengthen information handling capabilities of the ICRISAT Sahelian Center (ISC).

Phase I of this project ended in 1989 and a second phase was begun in 1990. IDRC has agreed to support the project in its second phase also. SATCRIS will continue to provide the information services started in the first phase and will make entry into newer areas of information that have potential for greater impact on users.

Objectives of SATCRIS (Phase II)

The broad objective of this phase is to build upon the strengths of Phase I by incorporating fresh components that will enable SATCRIS to provide new products and services to the National Agricultural Research Systems (NARS).

The specific objectives are:

- Expansion of the SATCRIS database to reflect the interdisciplinary nature of current SAT crops research;
- Development of time series datasets on the production and yield of crops of interest to SAT countries;
- Creation of an expert system on groundnut disease identification and control;
- Development of an user-friendly front-end to the SATCRIS database;
- Distribution of subsets of the SATCRIS database to NARS libraries and information centers in the SAT;
- Introduction of cost recovery charges for SATCRIS services from selected user groups;
- Continuation of the promotional work in Africa begun in phase I; and
- Enhancement of the information handling capabilities of ISC in Niamey.

Beneficiaries of the Project

The prime beneficiaries of the SATCRIS information products and services are ICRISAT scientists and researchers working at Patancheru, India; Niamey, Niger; Nairobi, Kenya; Lilongwe, Malawi; Bamako, Mali; Bulawayo, Zimbabwe; Aleppo, Syria; and El Batan, Mexico. Scientists, extension workers, academics, postgraduate students and research scholars working on the ICRISAT mandate crops in the NARSs of the SAT can also use SATCRIS services on request. Libraries and information centers can receive subsets of the SATCRIS database and/or training in the utilization of such subsets using Micro CDS/ISIS, a public-domain software.

Information Resource

SATCRIS database

The central resource of SATCRIS is its database, developed by obtaining monthly subsets of the CABI and Systems international d'information pour les sciences et la technologie agricoles (AGRIS) databases in machine-readable form. The data from these databases has been integrated with locally generated input to create a single, multi-disciplinary database on all five ICRISAT mandate crops. This database has been created with the help of a software package called BASIS. An inhouse-developed computer program is used for restructuring and conversion of data obtained from CABI and AGRIS before downloading them to the SATCRIS database (Fig. 1).

The SATCRIS database is built with inputs from predominantly agricultural databases. It is, therefore, lacking in coverage of data from interdisciplinary areas, such as food and nutrition, or biotechnology, which are not covered adequately in agricultural databases.

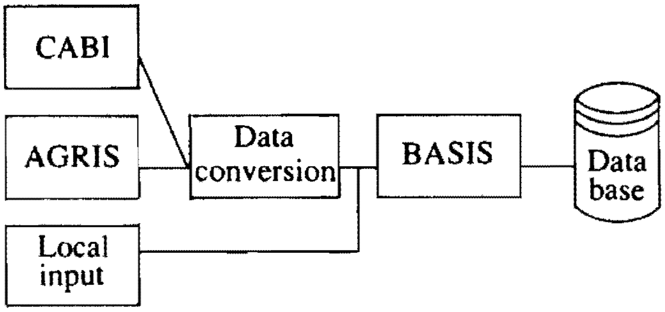


Figure 1. Semi-Arid Tropical Crop Information Service (SATCRIS) Database.

To fill these gaps in the SATCRIS database, it is planned, in the second phase of the project, to acquire and load data from such specialized databases as Food Science and Technology Abstracts (FSTA) and Biosciences Information Service (BIOSIS). Such a step would enable the SATCRIS database to be more comprehensive and provide wider and easier access to information relevant to the mandate crops not only from an agricultural science perspective but also from a broader phenomenological and life science perspective.

In the second phase of SATCRIS, it is proposed to develop a database containing time-series data on the production, yield, and distribution of crops of interest to the SAT countries. The idea is to develop such a database using traditional sources of statistical data as well as other sources such as journal articles and country reports. The possibility of using data from existing machine-readable sources (e.g., FAO, World Bank) will also be examined.

Databases on CD-ROM

SATCRIS often receives requests for search of information on crops and phenomena that are not covered by its own database. To satisfy such requests, SATCRIS uses the AGRICOLA (Agricultural OnLine Access) database of the U.S. National Agricultural Library (NAL), and the AGRIS database of FAO on CD-ROM (Compact Disc-Read Only Memory).

SATCRIS also has access to the Pesticide CD-ROM compiled by the Royal Society of Chemistry, UK, containing four databases. These databases provide quick access to pesticide products available worldwide, their active ingredients, structure, properties, and manufacturers. It is proposed to add the Dissertation Abstracts International (DAI) database on CD-ROM in the second phase of SATCRIS.

Information Products and Services

The following output products and services are provided:

- Monthly SDI service to researchers on request;
- On-demand literature search output;
- Abstracts service on all five crops in collaboration with CABI;
- Information analysis products such as literature reviews; and
- Document delivery service.

In addition to these products and services, it is envisaged to include the following services and products in the second phase:

- Distribution of subsets of the SATCRIS database suitable for use with Micro CDS/ISIS; and
- A prototype expert advisory system on groundnut disease identification and control.

SDI service

This is an automated current awareness service designed to regularly alert scientists to current literature that has a high probability of usefulness to them. This service uses current machine-readable data received each month from the CABI and AGRIS databases. These data are matched against users interest profiles, which are also stored as a computer file. The SDI service thus disseminates information to meet specific individual needs and interests. Furthermore, the service has built-in feedback that is regularly analyzed to ensure that SDI outputs continue to meet user needs and changing interests (Fig. 2).

Information search services

Requests for information that may be required in research project planning, problem solving, or decision-making are responded to by searching the SATCRIS database. The search output is provided free in the form of a list of references with abstracts wherever possible. Where the SATCRIS database is not adequate in meeting information requests, other databases available on line, from vendor systems [e.g., Dialog, Bibliographic Retrieval System (BRS), etc.] are searched. The cost of such searches, however, is charged to the client. SATCRIS also uses the

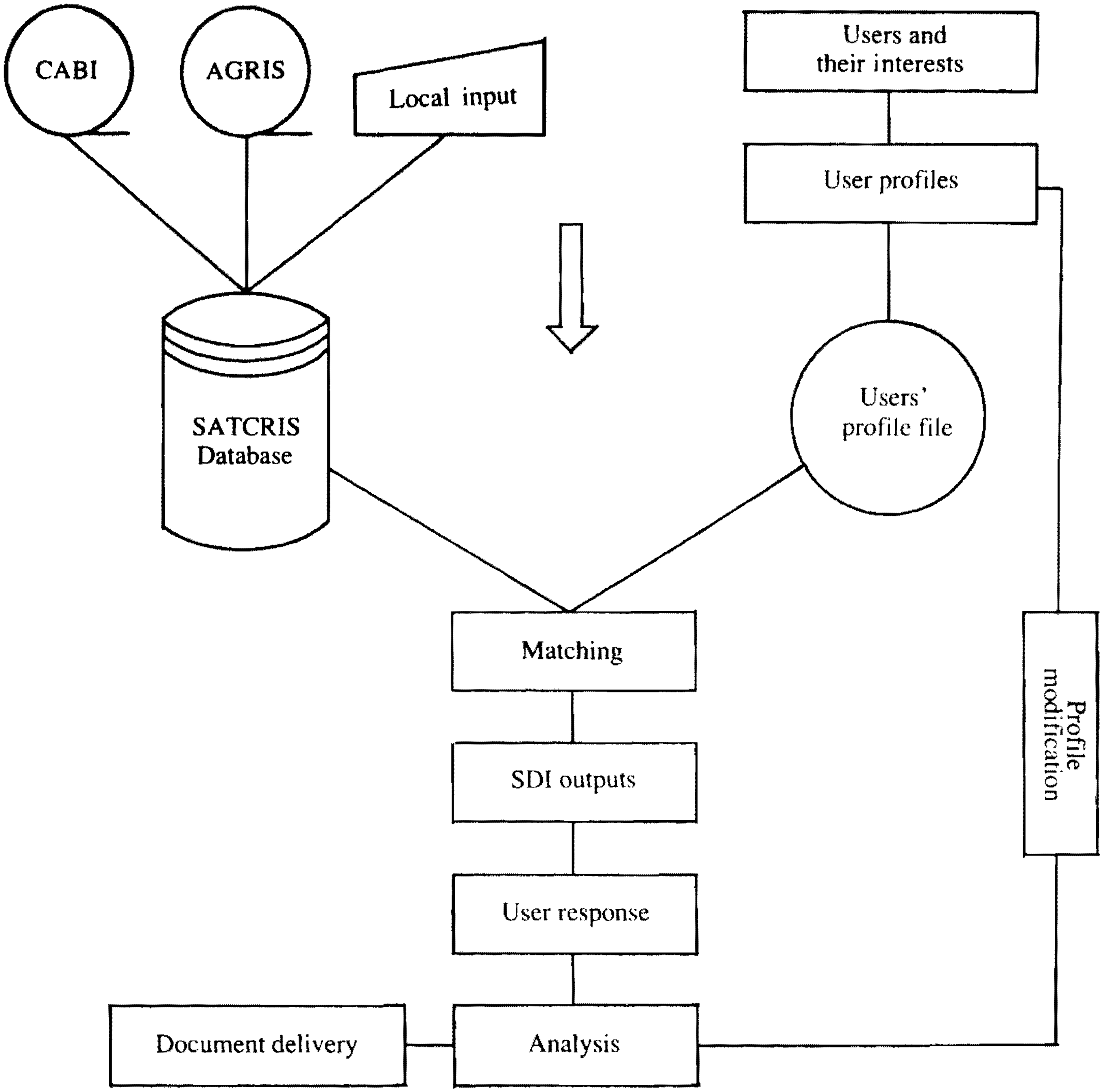


Figure 2. Selective dissemination of information (SDI) functional flowchart.

AGRICOLA and AGRIS databases on CD-ROM to respond to search requests.

Specialist abstracts service

SATCRIS collaborates with CABI to produce three specialist abstracts journals covering the five mandate crops: *Sorghum and Millets Abstracts*; *Chickpea and Pigeonpea Prompts*; and *Groundnut Prompts*.

These abstract journals are published by CABI and are mailed free to selected individuals and institutions all over the semi-arid tropics. SATCRIS staff provide to CABI input of information about ICRISAT's five mandate crops generated in ICRISAT and from other selected sources. *Sorghum and Millets Abstracts* commenced publication in 1987, and the other two journals in 1988.

Information analysis service

SATCRIS collaborates with scientists to produce special-subject reviews and critical evaluations of the literature on specific topics. SATCRIS information specialists interact with the scientists to understand and delineate the subject area concerned. In choosing subject areas or topics, the emphasis is on the usefulness of the repackaged information to scientists, researchers, and others in the SAT, since they do not have benefit of regular interaction with the expertise available in a center such as ICRISAT. The information analysis products are written by subject specialists whose services are contracted for a few weeks to several months depending upon the nature and scope of the subject. SATCRIS staff conduct a comprehensive search of relevant literature, and original documents identified as useful by the scientists are provided for their use. These products are later edited and published for use by all interested scientists.

Document delivery service

The SATCRIS SDI service and information search services generate requests for photocopies of original articles from researchers all over the world. SATCRIS provides single copies of documents in its collection, on demand. In addition, SATCRIS uses national and international libraries, depositories, and documentation and information centers in order to fulfill requests for the originals of documents on all the five mandate crops.

Database distribution

It is proposed in the second phase of SATCRIS to develop procedures to enable subsets of the database to be downloaded into a Micro CDS/ISIS database that can then be offered to NARS institutions. The subsets will be on specific topical areas, such as aflatoxin contamination of groundnuts, and striga, and could also be created on demand. The recipients of these subsets will mainly be libraries, but these subsets could also be made available to those scientists who have no access to library facilities.

Expert advisory system development on groundnut diseases

It is proposed to build, in the second phase of the project, a prototype expert advisory system on groundnut disease identification and control using an appropriate shell software package. It will identify appropriate crop management strategies and technologies to control and prevent spread or outbreaks of groundnut diseases. Diagnosis, recommendations, and alternative strategies will be presented to the user with explanations, illustrations, and an opportunity to record the user's reaction and provide feedback on field conditions. The system will generate a diary of past consultations and recommendations made for users, and monitor system performance and problem incidence for both NARS and ICRISAT.

SATCRIS Input to CABI and AGRIS Databases

SATCRIS is a user of CABI and AGRIS databases. It is, therefore, in the interest of SATCRIS to contribute to these databases. SATCRIS inputs ICRISAT-generated conventional and nonconventional literature to both AGRIS and CABI.

Specialized Databases on Microcomputer

SATCRIS is actively involved in the development of specialized databases for decentralized use on microcomputers. The idea is that SATCRIS will create and maintain such databases and make them available to the national and regional centers in the SAT. SATCRIS will keep these databases up-to-date and provide database updates on diskettes to users. In addition, SATCRIS will offer users training in the use of these databases, if required.

Two specialized databases already developed are: Aflatoxin problem in groundnuts, and *Busseola fusca* (a cereal stem borer). Information on a variety of primary documents, both conventional and nonconventional has been input to these databases. Micro CDS/ISIS has been used to create and maintain the databases.

The database on the aflatoxin problem in groundnut contains references of literature published during the last 30 years. Each record is provided with an abstract of the original article and a set of relevant keywords to facilitate search operation. This database has been created in response to the recommendations made in the International Workshop on Aflatoxin Contamination of Groundnut held at ICRISAT in October 1987.

Information Activities in Africa

SATCRIS operations are concentrated at ICRISAT Center at Patancheru, India. However, a subcenter of SATCRIS functions exists at ISC in Niamey, Niger. The subcenter has a documentalist who uses the infrastructure and facilities of the ISC and its library. The subcenter provides reference, retrieval, and document delivery services. The document delivery services are based on the collection of the ISC library and on a microfiche collection of primary literature useful to West African research on the five crops. The microfiche collection at ISC steadily expands with input from ICRISAT Center in India and consists of both conventional and nonconventional literature carefully chosen for its usefulness in the context of research in West Africa. Recently ISC has installed the SESAME database produced by the Centre de coopération internationale en recherche agronomique pour le développement (CIRAD), France. It provides access to more than 50 000 French agricultural literature references.

SATCRIS has conducted traveling workshops in eastern and southern Africa with the following aims:

- To improve awareness of scientists and other users to resources, services, and capabilities of SATCRIS;
- To build contacts with libraries and documentation centers to develop and improve exchange relationships; and
- To identify sources of conventional and nonconventional literature, and to explore formal and informal channels for ensuring the regular capture of such literature for the SATCRIS database.

During the second phase, it is proposed that SATCRIS will participate in regional workshops organized by ICRISAT for NARS scientists on sorghum, pearl millet, and groundnut with a view to make end-users better aware of SATCRIS resources and services.

Discussion

D.M. Tantera: I shall like to comment on information dissemination that has to be streamlined to educate all sections of farmers on technology adoption. Both speakers have placed emphasis on the technologies that are accessible to scientists and to an elite group of farmers. Though information dissemination is conducted with various means, the most effective one to reach farmers could be through radio broadcasts and TV satellite network for which there should be a support to use public funds.

K.J. Middleton: Is there likely to be a system developed that may replace CD-ROM in future?
M.A. Bellamy: The technology of CD-ROM is relatively recent; as of now it is still evolving. However, there is talk of WORM (Write Once Read Manytimes) drives, digital paper, etc. Many of these are still in the experimental stage.

B.R. Cooper: Could the speakers give some indication on how the information technologies might assist with the flow of information from farmers and extension workers back to the researcher with respect to solution of problems where expert assistance is required?
M.A. Bellamy: The University of Western Samaru developed a very good information system which incorporates the element you describe. Satellite technology has assisted in making this kind of link possible in the South Pacific region.

D. McDonald: What is the status of multilanguage publication facilities?
M.A. Bellamy: There is a great need for multilanguage publications for effective dissemination of information. However, automatic translation on computer is very expensive and it is difficult to produce a universal teaching system. Nevertheless, IRRI has made some effort in this direction and this is an important area that should be looked into.

C.A. Phangaphanga: Could you please elaborate on Information Analysis Products?
L.J. Haravu: Information Analysis Products consolidate information from several sources. Such information is often critically evaluated and/or reviewed by specialists to highlight significant findings, usable results, trends, etc.

M.S. Chinnan: Participants get excited when they see the availability and access to databases such as SATCRIS, SDI, and other specialized databases at ICRISAT. However, what is the mechanism to get access to user-free databases by workers outside ICRISAT?
L.J. Haravu: The service is free to all the users from NARSs except the private seed companies, consultants, etc. Such users are charged a cost-recovery fee.

N.R. Bhagat: Has ICRISAT developed linkages with the USDA/ARS National Agricultural Library on information transfer?
L.J. Haravu: A lot of exchange and mutual use of resources and services between ICRISAT and USDA/ARS does take place.

S. Desai: If the SDI service is provided on floppy drives instead of hard copies with a familiarization in use of ISIS through a 'README' file, the users can handle literature search on their own, thus sparing more time to base workers for further technology development.
L.J. Haravu: SATCRIS can provide SDI output as ASCII files or structure files for use with Micro CDS/ISIS. Users need to request specifically for this kind of output.

Handling and Processing of Groundnuts in the Americas

M.S. Chinnan[1], B.R. Cooper[2], and U. Wilson[3]

Abstract

*Groundnut (*Arachis hypogaea*) is cultivated in most regions of the Americas. The USA is the largest groundnut producer in the new world. It is also the largest producer of high quality groundnuts for edible use as it utilizes a high level of technology in production, processing, and handling. Most of that technology was developed in the USA and is adapted by other countries around the world where there is large-scale production of groundnut. Information in this paper covers 1) postharvest handling, processing, and utilization of groundnuts in the USA; 2) production and postharvest practices, and edible use of groundnuts in non-U.S. countries of the Americas; and 3) gives special emphasis to the improved postharvest handling system in the Caribbean region as part of the cooperation between the United States Agency for International Development Peanut Collaborative Research Support Program (USAID Peanut CRSP) and the Caribbean Agricultural Research and Development Institute (CARDI).*

Résumé

Manutention et traitement de l'arachide aux Amériques: *L'arachide (*Arachis hypogaea*) est cultivée dans la plupart des régions des Amériques. Les Etats-Unis sont le plus grand producteur d'arachide du Nouveau Monde. Les Etats-Unis sont aussi le plus grand producteur d'arachide de bouche de haute qualité, car ils utilisent une technologie très avancée pour la production, le traitement et la manutention. La majeure partie de cette technologie a été mise au point aux Etats-Unis et adaptée par d'autres pays à travers le monde qui ont une forte production d'arachide. L'information dans cette communication comprend (a) la manutention post-récolte, le traitement et l'utilisation des arachides aux Etats-Unis; (b) les pratiques de production et de post-récolte, et l'usage d'arachide de bouche dans d'autres pays des Amériques en dehors des Etats-Unis; et (c) le système de manutention amélioré post-récolte dans la région des Caraïbes, qui est accordée une grande place dans le cadre du programme de recherche coopérative internationale sur l'arachide entre l'Agence des Etats-Unis pour le développement international (USAID), le Programme américain d'appui à la recherche collaborative (CRSP) et l'Institut de recherche et de développement agricole des Caraïbes (CARDI).*

---

1. Professor, Food Safety and Quality Enhancement Laboratory, Department of Food Science and Technology, Georgia Experiment Station, University of Georgia, Griffin, GA 30223-1797, USA.
2. Systems Agronomist, Caribbean Agricultural Research and Development Institute, P.O. Box 766, Friars Hill, St. John's, Antigua, West Indies.
3. Agricultural Research Engineer, Caribbean Agricultural Research and Development Institute, University of the West Indies, Mona Campus, P.O. Box 113, Kingston 7, Jamaica, West Indies.

This paper was made possible through support provided by the Office of Agriculture, Bureau of Research and Development, U.S. Agency for International Development under Grant No. DAN-4048-G-00-0041-00.

Chinnan, M.S., Cooper, B.R., and Wilson, U. 1992. Handling and processing of groundnuts in the Americas. Pages 241–248 *in* Groundnut – a global perspective: proceedings of an international workshop, 25–29 Nov 1991, ICRISAT Center, India (Nigam, S.N., ed.). Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

America can be divided into three major areas, North America, Central America and the Caribbean, and South America. North America, which includes the United States, Canada, and Mexico, produces more than 67% of the Americas' crop of groundnuts (*Arachis hypogaea*), whereas the United States produces more than 97% of North America's crop. The South American countries produce about 30% of the crop with Argentina and Brazil dominating the production (90% of the South American production). The USA employs highly mechanized production, processing, and handling techniques. Argentina and Brazil have some very large highly mechanized farms with mechanized on-farm handling and processing systems, but they also have small-scale subsistence farmers like other non-U.S. countries in the Americas. This paper is primarily about handling and processing of groundnuts; actual production statistics can be found elsewhere. However, it is important to relate some relative production information and get a perspective on the level of sophistication in production and post-harvest operations.

Supply Distribution and Use of Groundnuts in Food Products

Distribution of in-shell groundnuts produced in the USA for the 1989 crop (NPC 1990) is given in Figure 1, which shows that the majority of the crop is utilized for food (57.6%) and only about 12% is crushed for oil. The USA is the largest producer of edible groundnuts

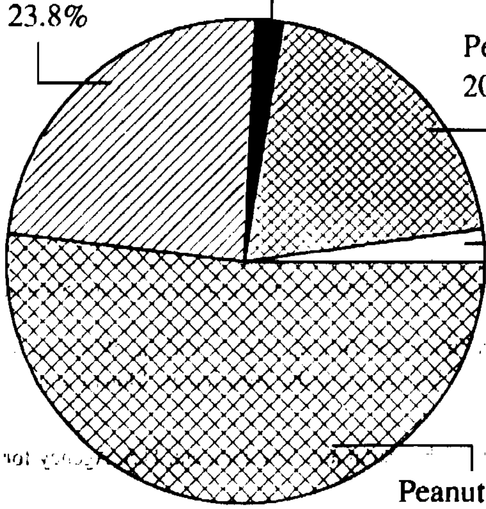


Figure 1. Supply distribution of in-shell groundnut in the USA.

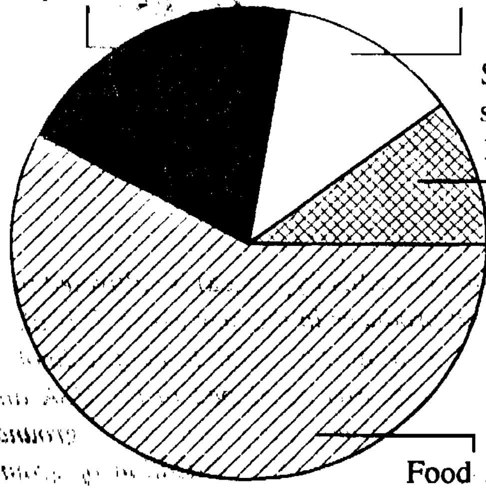


Figure 2. Use of shelled groundnut in U.S. products.

and the proportion of shelled groundnuts in various food items is listed in Figure 2. Data for Figure 2 was also obtained from the National Peanut Council (NPC) (1990). Most current data similar to those presented in Figures 1 and 2 are not available for other countries or regions in the Americas. However, relevant information for specific countries is presented below.

Argentina

More than 90% of the production is in Córdoba Province, where advanced production technology is used. About 75% of the crop is crushed for oil and 25% is exported or domestically consumed as either roasted groundnuts or peanut candy.

Brazil

Approximately 80% of the crop is crushed or exported and the other 20% is consumed domestically as roasted nuts or peanut candy. Groundnuts are grown both on a small scale by farmers using a low level of technology and on a large scale by farmers using advanced production and handling methods; however, the ratio of the two types of production systems employed is unavailable.

Paraguay

More than 50% of the groundnut production is under a high level of technology and most of the crop is crushed for oil.

Bolivia and Peru

These are relatively small groundnut producing countries. Most of the groundnuts are produced on a small scale by farmers employing a low level of technology. Groundnuts are mainly used for domestic consumption as roasted groundnuts, peanut brittle, or edible oil.

Venezuela

High technology production is increasing in Venezuela. Approximately 50% of the crop is processed for oil and the remainder of the crop is consumed domestically.

Caribbean and Central America

The Caribbean Community (CARICOM) comprises 12 English speaking countries (Antigua, Barbados, Belize, Dominica, Grenada, Guyana, Jamaica, Montserrat, St. Kitts-Nevis-Anguilla, St. Lucia, St. Vincent, and Trinidad and Tobago). Most of the groundnuts are grown on small farms using a very low level of technology. However, a project on development of improved postharvest and handling methods is currently funded by the United States Agency for International Development Peanut Collaborative Research Support Program (USAID Peanut CRSP) in collaboration with the Caribbean Agricultural Research and Development Institute (CARDI). Locally grown groundnuts are consumed almost entirely as snack food with some being processed into peanut butter. A small amount of the crop is crushed for oil.

Production of groundnuts in the Central American countries (excluding CARICOM Belize) is insignificant. For example Honduras grows groundnuts on less than 100 hectares on very small farms using a low level of production technology. Groundnuts are primarily used in the roasted form. Both quality and yields are very low.

Harvesting and Postharvest Handling

These steps include digging, harvesting, curing/drying, storing, and shelling. In the USA these practices are highly mechanized and each practice is discussed in greater detail below; whereas, elsewhere, with the exception of the regions identified earlier under high technology production, almost all the postharvest operations are done by hand. There is some production of groundnuts in the non-U.S. countries using intermediate postharvest technology which is discussed separately under the USAID Peanut CRSP – CARDI project.

Digging

Digging time. Groundnut is an indeterminate crop and it continues to produce pods as long as the plants are healthy. Assessment of maturity to determine the digging/harvesting date is very critical. The methods range from digging after a certain number of days from the sowing date to highly sophisticated analytical techniques requiring instrumentation valued at thousands of dollars. The technique employed may take a few minutes to several hours to obtain the results. There are basically four methods with some variations to determine crop maturity (Sanders et al. 1982). These are 1) indirect methods (days after sowing, heat units), 2) relative color evaluation (internal hull color, oil color, methanol extract, pod maturity profile, also known as the hull-scrape method), 3) weight and weight relationships (seed density, seed hull ratio), and 4) quantification of a specific component (AMI-arginine maturity index). No single technique can be used to accurately predict the optimum digging time; any estimate, however, is verified by another shellout evaluation for optimum yields. The hull-scrape method, described in detail by Sanders et al. (1982) and Johnson (1987), needs particular mention as it is being successfully employed in assessing the maturity of runner groundnuts. The method requires a special color chart and a pocket knife. The knife is used to scrape away the exocarp (outer hull covering) to expose the mesocarp. The degree of darkness of the mesocarp is dependent on the pod maturity, and it changes from white to yellow to orange to brown and to black as the groundnut matures. Maturity is estimated by matching the scraped groundnuts with colors on the chart.

Mechanics of digging. The oldest and the simplest method is hand digging, a labor-intensive operation, which is employed by small-scale farmers outside the USA. However, the mechanized farms use one of the two types of diggers based on the windrow type produced. Earlier types lifted the groundnuts from the soil, shook the soil from the plant and deposited the plants at random in the windrow. Most new diggers are of the second type, which place the plants in such a way that the plants are in inverted position in the windrows exposing the pods to the sun. Inverting the plants has numerous advantages including quicker loss of moisture for better quality of groundnuts, and also reduced likelihood of invasion by *Aspergillus* spp (Woodroof 1983).

Field curing

At digging groundnuts normally contain between 35 and 50% moisture, which must be reduced for safe storage. Moisture reduction is normally done in two stages. The first stage is drying the plants in the field in windrows before removing the pods from the vines, manually or mechanically; this step is called field curing. The second stage is additional drying down to 10% moisture or less after removing the pods from vines.

Removing pods from vines (threshing/combining)

Mechanized farms, which include most of the farms in the USA, use combines for harvesting groundnuts from the windrows. It is common practice to begin combining when the seed moisture is 20 to 25%, this being generally suitable for optimum quality and energy efficiency. Other mechanical methods used are the stack pole and once-over harvesting procedure.

Drying

It has been very well documented that the seed moisture content of groundnuts should not exceed 10% for safe storage. The moisture of the freshly harvested groundnuts must be reduced promptly to prevent quality losses from possible proliferation of *Aspergillus flavus* and/or *Aspergillus parasiticus* resulting in aflatoxin production. Moisture reduction under fairly controlled conditions is highly recommended. Slow removal of moisture allows aspergillus growth, whereas rapid moisture reduction affects the flavor and other quality characteristics adversely. Combined groundnuts are dried in wagons at air temperature not exceeding 45°C, and preferably not exceeding 35°C, with a minimum air flow rate of $10m^3$ per minute per m^3 of groundnuts (Young et al. 1982). More recent curing procedures using alternate periods of 'air on' and 'air off' appear to give satisfactory results with reduced energy requirements while maintaining quality. Considerable literature is available on the design of appropriate dryers regarding heat and airflow requirements (Young et al. 1982).

There are several other alternative drying systems, such as sack drying, vacuum drying, infrared drying, and use of heat-pump systems and solar systems. None of these systems are widely used.

Storage

Groundnut is a semiperishable commodity; it may be held up to 5 years under optimum conditions, but under abusive storage conditions it may become inedible in less than a month due to mold, insects, or development of undesirable flavor characteristics. At 20°C unshelled groundnuts may maintain acceptable quality for 6 months; whereas for shelled groundnuts the storage period is reduced to 4 months. In addition to low temperature, relative humidity of the storage environment should not exceed 65–70%. High humidity combined with high temperature is the most common factor leading to growth of aspergillus molds and possible production of aflatoxin, a highly potent carcinogen. The control of moisture in groundnuts during storage can be accomplished by adequate circulation and control of the relative humidity.

Shelling (milling)

This operation consists of cracking the pod, removing the seed from the cracked pod, and separating the clean seed from the pod. This operation may be performed by a simple manual process yielding the highest percentage of undamaged seeds or by very large mechanical shellers handling hundreds of tons of groundnuts per day. The most common mechanism in mechanical shellers is a drum-shaped device with heavy, curved grates forming the lower half of the drum and a revolving beater inside the drum that crushes the pods by impacting them against the ridges in the grates. The clearance is adjusted to avoid injury to the seed. Groundnuts seeds, broken shells, and fragments drop through the grate opening, and the shells are separated pneumatically.

A commercial shelling (milling) process involves many steps (Figure 3). The types of operations needed depend upon the intended end use. Three primary end uses for groundnuts are oil crushing, seed, and edible use. Sorting of shelled nuts is achieved with high-speed electronic sorters. In low technology environments color sorting for sound and damaged seeds is done manually by visual inspection.

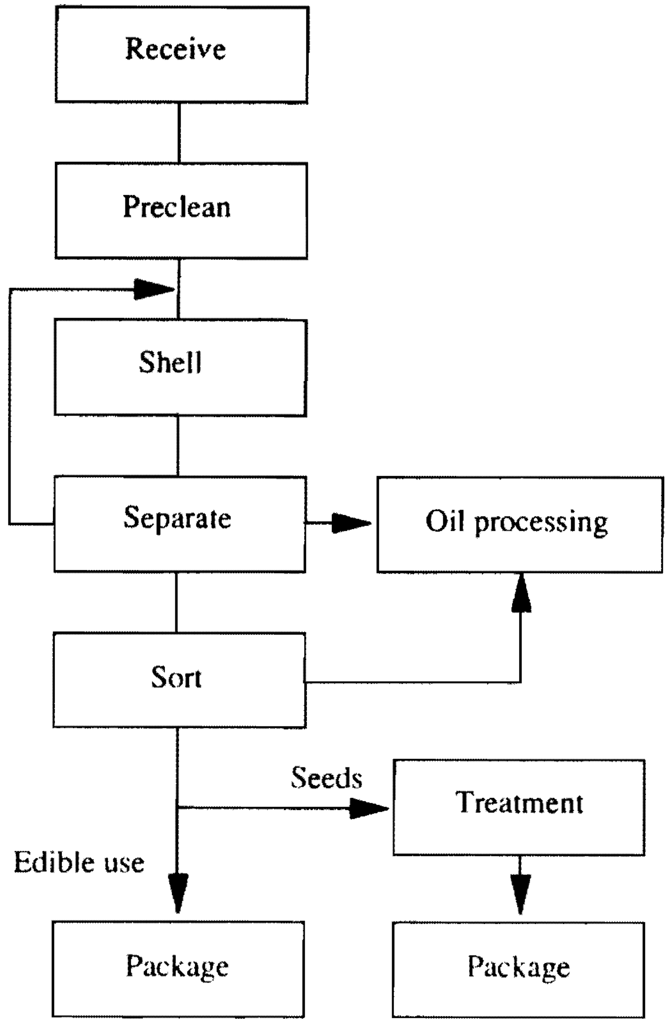


Figure 3. Primary operations in groundnut milling.

Processed Groundnut Products and Confections

Groundnuts for edible consumption may be processed into many different types of products: roasted groundnuts (dry and fried), peanut butter, groundnut candies and confections, and groundnut as an ingredient in other food products such as cereals, cake mixes, ice cream, pasta products, etc. Peanut butter may be combined with other food products or ingredients such as fruit jellies, or it may be used in cookies, crackers, and bakery goods. Roasted groundnuts may be flavored in various ways, or coated with milk chocolate. In a U.S. grocery market it is possible to find more than 50 commercially sold food products containing groundnuts. About 75% of shelled groundnuts in the USA marked for edible use are destined for salted groundnuts and peanut butter (Figure 2). Figure 4 shows product flow in a typical groundnut processing plant for salted groundnuts, roasted groundnuts and peanut butter. Groundnuts processed for end use other than salted groundnuts or peanut butter will have some additional processing steps or a variation of those presented in Figure 4.

An important step in peanut butter making is addition of a stabilizer to prevent oil separation. The stabilizer is added in the peanut butter milling or grinding step. The choice of stabilizer depends on the process, packing season, fill and storage temperature, and desired flavor characteristics of the final product. A list of stabilizers frequently used in making peanut butter, adapted from Young and Heinis (1990), is given in Table 1.

Advances in packaging techniques such as vacuum packaging, gas impermeable packaging materials including laminated foil packs (polyethylene, aluminum foil, and polyester), and inert gas flushing have resulted in significant increase in shelf-life, due to delay in the onset of rancidity of groundnut products. A wide variety of packaging materials and processes are commercially employed to match the product and target.

Postharvest Handling Systems in the Caribbean

The Peanut CRSP has been active in the Caribbean basin since 1987 with a goal of improving postharvest handling operations for the small-scale groundnut producers. Initial emphasis was in the five CARICOM countries of Antigua, Belize, Jamaica, St. Vincent, and Trinidad. The collaboration in these countries has been between the University of Georgia and CARDI. Current Peanut CRSP activities are focused in Jamaica and Belize.

Harvesting and threshing

Harvesting is the most labor-intensive and costly single operation on groundnut farms in the Caribbean. Except for a few selected large farms, all the digging, harvesting, and picking the pods from the vines is done manually. This operation costs up to 25% of the production cost. Small Japanese threshers (manufactured by CECOCO) were first modified and tested to adapt to the farming situations in Belize and Jamaica. Threshers were adapted to operate using tractor power-take-off drive or a gasoline engine. Appropriate mechanisms or attachments to transport the threshers in the field were designed to utilize a three-point hitch of a tractor, or to be mounted on a frame with wheels to be pulled with a pickup truck or an animal. Extensive field trials were

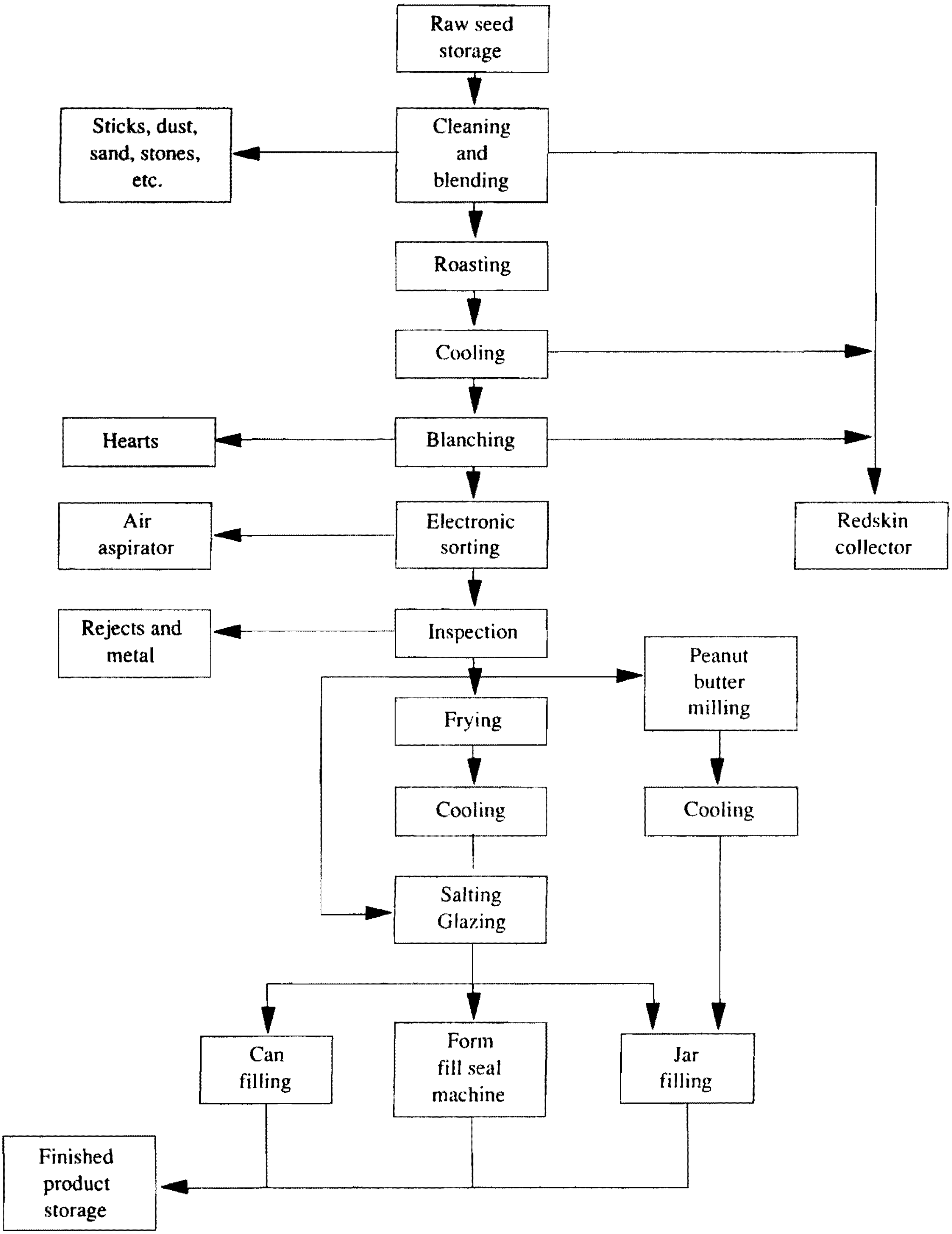


Figure 4. Product flow in a typical groundnut processing plant.

Table 1. Stabilizers frequently used in peanut butters.[1]

Product	Product type	Content in butter (%)	Melting temp (°C)
Anderson-Clayton Foods, Richardson, Texas			
Shur Set P	Soybean oil	1.5–2.0	60
Durkee Foods, Louisville, Kentucky			
Durkee 27	Palm oil	1.5–2.0	58–62
Durkee 07	Cottonseed oil	1.7–2.0	60–64
Dur-Em 127	Mono- and di-glycerides	1.7–2.0	60–63
Eastman Chemicals, Kingsport, Tennessee			
Myvatex	Palm oil (H)[2] and monoglycerides	1.5–2.0	63
Grinstead Products, Industrial Airport, Kansas			
HPOK	Hard palm oil (kosher)	1.5–2.5	57–62
Lipodan MS2-K	Rape seed oil, soybean oil, and palm oil (H)	1.0–2.0	59–61
Lipodan PS-K	Palm oil, palm oil (H)	1.0–2.0	62
Kraft Industrial Foods, Memphis, Tennessee			
Altmul16K	Mono- and di-glycerides	1.0–2.0	62
Procter and Gamble, Cincinnati, Ohio			
Fix X	Vegetable oil	1.5–2.0	57

1. Other manufacturers are available.
2. H = hydrogenated.

done to evaluate a design acceptable to the local farmers. Detailed drawings with various possible options of powering and transporting the threshers have been developed. The drawings are detailed and simple enough to enable local artisans to fabricate the thresher. A thresher with a gasoline powered engine was fabricated in Belize and shipped to Antigua.

Drying and storage

Inadequate drying and storage facilities are among the major constraints in producing quality groundnuts in the Caribbean. Traditionally, groundnuts are dug, left in the field on vines to dry, hand picked, and dried in open fields or on paved surfaced (called barbecuing in Jamaica); or, alternatively, hand picked and, immediately after drying, washed in water if soil is adhered to the pods, and dried in open fields or on paved surfaces. The sun-dried groundnuts in the field or on paved surfaces are then put into storage. In most cases groundnuts are not dried to the desired moisture level of less than 10%; and in addition the storage areas may be poorly ventilated, particularly during the hot and humid summer days. Dryers with inexpensive kerosene burners and gasoline-powered blowers were tested in Belize and Jamaica. Kerosene-burner dryers have been accepted by the farmers in Belize. Artificial drying is extremely important in Belize where it is wet and humid during most of the year and particularly during the harvest season. Acceptability of such dryers in Jamaica still remains to be seen. Design and details for fabricating and installing the dryer types installed in Belize and Jamaica are available from the senior author. Currently installed dryers are of 1000 kg and 3000 kg capacity. Designs for other capacities are also available.

Protocols for designing and using storage facilities appropriate for various regions in the Caribbean have been developed. Storage experiments have been conducted on on-farm facilities to evaluate the quality of groundnuts. Details are given in the Peanut CRSP (1990) report.

Shellers

In the Caribbean, farmers shell groundnuts by hand. A few processors in the region use mechanical shellers.

Hand-operated groundnut shellers designed by CARDI-Jamaica have been tested locally and have met with some success. However, these shellers are too heavy to move from one location to another. A pedal-powered sheller was developed by the Peanut CRSP – CARDI project and has been tested in Jamaica and Belize. The results have been very encouraging.

Processing and products

Most of the groundnuts produced in the Caribbean are roasted and consumed locally. A local processor in Belize manufactures peanut butter (marginal quality) that is sold to the local market. There are a few processors in Jamaica who market salted groundnuts and groundnut brittle from locally grown groundnuts. Peanut butter and chocolate candy in Jamaica are manufactured from either imported groundnuts or groundnuts grown on relatively large mechanized farms (farm size more than 10 hectares). Trinidad has two large-scale groundnut processing plants. The products include groundnut punch, peanut butter, chocolate-coated candy, and roasted and salted groundnuts. However, Trinidad imports groundnut because there is no local production.

Future Prospects

Belize has increased groundnut production from 40 to 200 ha and is exporting some groundnuts to neighboring Caribbean countries. Belize has a successful farm cooperative infrastructure. This allows them to easily adapt intermediate level production and postharvest technologies. The technologies developed under the Peanut CRSP – CARDI collaboration are used by the Belizean cooperatives. Models for integrated systems of postharvest operations suitable for a given region are being developed. Results of cost analysis and socioeconomic studies will be used to evaluate the potential adaptability of the technologies. Increased utilization of groundnuts and groundnut products is possible with the availability of high quality groundnuts at reasonable prices.

References

Johnson, W.C. 1987. Maturity assessment. Pages 13.1–13.4 *in* Georgia peanut production guide, Athens, GA 30602, USA: University of Georgia, College of Agriculture.

NPC (National Peanut Council). 1990. Peanut Industry Guide 1990–1991. The Peanut Farmer 26(8):1-270.

Peanut CRSP (Peanut Collaborative Research Support Program). 1990. Postharvest handling systems for the small groundnut producer. Annual Report of the Peanut Collaborative Research Support Program (Peanut CRSP) 1989/90:193–205.

Sanders, T.H., Schubert, M.A., and **Pattee, H.E.** 1982. Maturity methodology and postharvest physiology. Pages 624-654 *in* Peanut science and technology (Pattee, H.E., and Young, C.T., eds.). Yoakum, TX, USA: American Peanut Research and Education Society.

Woodroof, J.G. (ed.) 1983. Peanuts: production, processing, products. 3rd edn. Westport, CT, USA: AVI Publishing Co.

Young, C.T., and **Heinis, J.J.** 1990. Manufactured peanut products and confections. Presented at the Training Course on Quality Evaluation and Utilization of Food Legumes and Coarse Grains, 1–26 Oct 1990, Bangkok, Thailand. Bangkok, Thailand: Kasetsart University.

Young, J.H., Person, N.K., Donald, J.O., and **Mayfield, W.D.** 1982. Harvesting, curing and energy utilization. Pages 458-485 *in* Peanut science and technology (Pattee, H.E., and Young, C.T., eds.). Yoakum, TX, USA: American Peanut Research and Education Society.

Some New Groundnut Products in Southeast Asia

L.R. Beuchat[1], P. Chompreeda[2], V.V. Garcia[3], C. Oupadissakoon[2], V. Haruthaithanasan[2], R.R. del Rosar[3], and R.C. Mabesa[3]

Abstract

*Groundnuts (*Arachis hypogaea*) are grown throughout Southeast Asia where they represent an important source of protein and calories in the diets of many people. The traditional forms in which they have been consumed vary considerably from roasted and boiled seeds to sauces and beverages. Food technologists in several Southeast Asian countries are actively researching new ways to increase groundnut utilization through the development of new products and the modification of traditional ones. A brief summary of recent research efforts is presented, with particular emphasis on activities in Thailand and the Philippines.*

Résumé

***Quelques nouveaux produits arachidiers dans le Sud-Est asiatique:** L'arachide (*Arachis hypogaea *L.) est cultivée dans tout le Sud-Est asiatique, où elle représente une source importante de protéines et de calories pour le régime alimentaire de bien des habitants. Les formes traditionnelles sous lesquelles elle est consommée varient considérablement, des grains torréfiés ou cuits à l'eau jusqu'aux sauces et boissons. Les technologistes alimentaires de plusieurs pays du Sud-Est asiatique conduisent des recherches sur la manière d'en accroître l'utilisation en mettant au point de nouveaux produits et en modifiant les produits traditionnels. Un bref résumé des efforts de recherche effectués récemment est présenté, surtout en ce qui concerne les activités de la Thaïlande et des Philippines.*

Groundnuts (*Arachis hypogaea*) are consumed in many forms in throughout Southeast Asia. Some groundnut products, for example roasted and boiled forms, are popular throughout the region. Other products are consumed only in certain countries or areas within a country. Most of these groundnut products are prepared by traditional methods. However, new processing technologies and a recent increase in food product development research activities have resulted in several groundnut-based products exhibiting high potential for success in the marketplace. Major research efforts have been expended in Thailand, the Philippines, and Taiwan. The work in Thailand and the Philippines has been supported largely by the United States Agency for International Development Peanut Collaborative Research Support Program (USAID Peanut CRSP) and their research successes are reported.

1. Professor, Food Safety and Quality Enhancement Laboratory, Department of Food Science and Technology, Georgia Experiment Station, University of Georgia, Griffin, Georgia 30223-1797, USA.
2. Principal Investigator (Peanut CRSP), Assistant Professor, and Associate Professor and Head of Department, Department of Product Development, Faculty of Agro-Industry, Kasetsart University, 50 Paholyothin Road, Bangkok 10900, Thailand.
3. Associate Professors, and Associate Professor and Director, Institute of Food Science and Technology, College of Agriculture, University of the Philippines at Los Baños, College, Laguna 4031, the Philippines.

This paper was made possible through support provided by the Office of Agriculture, Bureau of Research and Development, U.S. Agency for International Development under Grant No. DAN-4048-G-00-0041-00.

Beuchat, L.R., Chompreeda, P., Garcia, V.V., Oupadissakoon, C., Haruthaithanasan, V., del Rosar, R.R., and **Mabesa, R.C.** 1992. Some new groundnut products in Southeast Asia. Pages 249–255 *in* Groundnut – a global perspective: proceedings of an international workshop, 25–29 Nov 1991, ICRISAT Center, India (Nigam, S.N., ed.). Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Description of Products

Thailand

Extensive research has been carried out by the Department of Product Development, Kasetsart University (KU), Bangkok, on improvement of traditional groundnut products and development of new groundnut products suitable for the Thai market, which also have great potential for acceptance by consumers in other Southeast Asian countries (Haruthaithanasan 1989). The following includes the description of some of the products.

Groundnut-based yogurt. Groundnut milk was prepared from groundnut protein isolate. The process of preparing groundnut yogurt involved pasteurization of groundnut milk containing 5% lactose, cooling, inoculating with yogurt culture, incubating at 37°C for 4 h, and refrigeration. Sponge cake and *Kanom-Sommanus* were prepared using groundnut yogurt flour to replace 25% of wheat flour and 50% of desiccated coconut (*Cocos nucifera*) flake. The acceptability of the sponge cake was very poor. *Kanom-Sommanus* prepared from 25% of groundnut yogurt flour was accepted with a higher score than the control.

Groundnut bars. A modified bar was developed with a peanut-butter base. An original formulation consisted of 65 to 69% ground roasted groundnut, 3.3 to 3.5% of finely ground roasted rice (*Oryza sativa*), 4.1 to 4.3% hydrogenated fat, 1.6 to 1.7% sugar, 0.8 to 0.9% salt, and 9.8 to 10.3% maltose syrup. The addition of some roasted desiccated coconut was also preferred.

A recently improved formulation contains 72% finely ground roasted groundnuts, 12% maltose syrup, 9.5% finely ground sugar, 3% roasted desiccated coconut, 2% finely ground roasted rice, 1% roasted sesame (*Sesamum indicum*) seed, and 0.5% salt. All ingredients were mixed at 60°C and passed through a peanut-butter mill. The mixture was then pressed into a rectangular-shaped mold.

Consumer testing was conducted at KU during the National Agriculture Fair. Questionnaires (251) were randomly distributed to consumers of different backgrounds. Results showed that more than 57% of the consumers found this product acceptable. About 74% of the consumers indicated their interest in buying it.

Groundnut-fruit spread. This groundnut product is made from mixing peanut butter, in the ratio of 20–50% by weight, with tropical preserves, jam, fruit butter, or fruit paste. Pineapple, banana, and papaya jam and peanut butter were prepared in ratios of 1:4 (80% peanut butter), 1:3, 1:2, 1:1, respectively. A sensory panel indicated that a mixture of banana and papaya at the ratio of 1:3 was preferred to pineapple. Sourness was an undesirable characteristic in the product. Further study will be done on spread containing banana and papaya in an attempt to improve quality and acceptability.

In another study, a spread containing banana, papaya, and durian powders mixed with peanut butter was developed. Durian powder was used because it is perceived by many Thais as having a natural fruit flavor. A ratio of 1:3 (fruit powder-peanut butter) was moderately acceptable, but a mixture of 20% fruit powder and 80% peanut butter (ratio 1:4) was highly acceptable.

Chocolate-flavored groundnut beverage. Milk-like beverages prepared from oilseeds have great potential as a nutritional substitute in areas where cow milk is too expensive or is indigestible. A study was undertaken to develop a chocolate-flavored groundnut beverage. The objectives were to optimize the sugar and chocolate ratio in the beverage and to investigate consumer acceptability of the product. Defatted flour was used for the preparation of groundnut protein isolate by an aqueous extraction method.

An acceptable chocolate-flavored groundnut beverage containing 3.5% groundnut protein, 3.5% fat, 8% sugar, 0.7% cocoa powder, 0.1% stabilizer, and water was produced. More consumer tests are needed to confirm acceptance of the product. Formulation of a milkshake-type product based on groundnut protein isolate may be possible following a similar process. Fruit-flavored beverage products may be another avenue for expanding the utilization of groundnuts in the form of beverages simulating dairy products.

Chicken patties extended with groundnut flour. Important benefits of using vegetable proteins as meat extenders include cost reduction and increased product yields. The objective of this study was to evaluate the quality attributes of ground chicken extended with defatted (DPF) and partially defatted (PDPF) groundnut flours.

Cooking losses and shrinkage of extended ground chicken patties were less than those of pure chicken patties. Extending ground chicken with groundnut flour increased the percentage of water retained by patties during cooking. The shear force required to compress extended patties was less than that required for the control. The higher water-retention properties of extended ground-chicken patties contributed to their increase in tenderness as indicated by lower compression values.

The color scores for extended ground-chicken patties with 20% DPF and 10% PDPF were lower than that of the control. Higher scores for firmness and flavor were assigned to the control patties, but the pure chicken patties were less tender than extended patties. All extended chicken patties had a groundnut odor, especially those extended with PDPF. There was a slight difference in cohesiveness among the products, but no difference in juiciness was observed. There was also no difference in overall preference scores among the control and the extended patties with 15% and 20% DPF and 10% PDPF.

These results indicate that extended chicken patties can be prepared by using either DPF or PDPF. Extending with PDPF is more appropriate in Thailand because of lower processing costs.

Quality evaluation of fried groundnut patties. Homemade fried groundnut patties have been sold in Thai markets for many years. However, the quality of the fried groundnut patties has not been scientifically investigated. Determination of pattie qualities is necessary before standards can be set against which improvements can be made. Samples of fried groundnut patties were purchased from seven locations in the Bangkok area for determination of physical, chemical, microbiological, and sensory attributes. Three replications were done at each location over a 3-month period. The results showed that the quality of the patties differed at each location. As many as 88% of the samples contained aflatoxin in excess of the public health specification level (20 ppb). Samples varied in the quantity of groundnut seeds, weight, size, and thickness. Chemical composition also varied. Patties had peroxide values of 7.5 to 33.1 meq kg^{-1}, which resulted in a pronounced rancid flavor that was unacceptable by sensory panelists.

Ice-cream product containing groundnut protein isolate. The effects of groundnut protein isolate on qualities of ice cream were studied. Spray-dried groundnut protein isolate was used to replace non-fat milk solids. Optimization of levels of the protein isolate and coconut powder in ice cream was studied. Ratio profile tests were conducted to evaluate sensory characteristics of the products. Durian powder, jack fruit paste, and cocoa powder were used for flavoring the ice-cream formula. Consumer acceptance of the highest ranked ice-cream formula was studied using 45 untrained panelists. Sensory evaluation and response surface methodology indicated that the optimum ice-cream formula contained 7.8% groundnut protein isolate and 5.0% coconut powder. Durian-flavored ice cream was ranked highest of three products.

Tube feeding product containing groundnut protein. Development of a prototype tube feeding product for hospital use consisted of selection of raw materials, formulation under control constraints, selection of drying processes, analyzing quality attributes, testing for shelflife, and testing for consumer acceptability. Results showed that groundnut protein concentrate performed well as a source of protein because it caused minimal product foaming. Pumpkin was selected as the source of vitamin A because of its low price and year-round availability. A tube feeding product was formulated, consisting of whole egg powder, pumpkin, groundnut protein, whole milk powder, maltodextrin, and water. Spray drying at 190°C produced a good quality, light yellow powder with good aroma.

The product was a very good source of essential amino acids. The protein quality of the product was comparable to that of casein. Product stored in cans at 31°C was still accepted by panelists after 15 weeks of storage.

Fifty nurses from hospitals in Bangkok evaluated the tube feeding product. They liked the sensory qualities of the product but had difficulty in dissolving it.

Groundnut-supplemented Chinese-type noodle in Thailand. Groundnut flour is an effective fortifier of wheat flour products because of its high protein content and also because it contains more lysine than wheat flour. Chinese-type noodles were prepared by replacing wheat flour with 15, 17, or 19% low-fat groundnut flour. Four noodle formulas, including a control, were subjected to sensory tests. The color, firmness, and groundnut odor scores of noodles supplemented with 15 and 17% groundnut flours were not significantly different from the control. The formula containing 19% groundnut flour was very pale in color and had a strong groundnut odor. Noodles supplemented with 17% of the flour contained 18% protein.

Supplemented Chinese-type noodles were subsequently produced at a factory in Bangkok. Defatted groundnut flour (11.5%) was used to replace wheat flour in noodles without causing problems with processing equipment. The factory produced one batch of noodles containing 6000 individual aluminium foil packages. Quality characteristics of groundnut-supplemented noodles were compared with those of control noodles.

Protein content of groundnut-supplemented noodles was 50% higher than that of the control. Other characteristics of test and control noodles were similar. Hot and sour seasoning (*Tom Yum*) was selected to season groundnut-supplemented noodles. Sixty consumer-type panelists evaluated the supplemented and the control noodles served with laboratory-formulated hot-sour seasoning. Panelists preferred the size and firmness of control noodles over that of groundnut-supplemented noodles. However, panelists neither liked nor disliked all sensory qualities.

Consumer tests designed to evaluate groundnut-supplemented noodles were conducted using three groups of participants. One test was conducted at Kasetsart University using 200 participants from the general public. Noodles were boiled in water for 5.5 min, after which *Tom Yum* seasoning was added and the noodles were served to Thai consumers. The second test was conducted at the Department of Food Science and Technology, University of Georgia, using 114 participants. Noodles were prepared as in the first test except chicken seasoning was used instead of *Tom Yum* seasoning. A third test was done using 120 students (9–12 years of age) from a secondary school in Nakorn-Patom area of Thailand. Chicken seasoning was also added to the noodles served to these consumers.

All groups of consumers accepted the groundnut-supplemented noodles. The U.S. consumers liked this kind of noodle better than the Thai consumers. This may be due to the soft texture of the noodle. Thai and U.S. consumers recognized the nutritive value of the groundnut-supplemented noodles as a factor for buying more noodles in the future if they were available.

Nutritious snack for school-age children. Linear programming was used to generate formulas for crispy snacks for school-age children, aiming at a low cost of ingredients and a product containing 25% of the Recommended Daily Allowance (RDA) of nutrients for children 7–9 years of age. The protein sources in the formulas were skim milk powder, egg yolk, whole groundnut flour, and defatted groundnut flour.

Four recipes were accepted by panelists. A recipe with whole flour received the highest score for overall acceptability. The protein, vitamin A, thiamine, niacin, calcium, phosphorus, and iron content in all recipes were higher than in commercial snacks.

Snack containing groundnut flour and pregelatinized tapioca flour. Defatted flour from Tainan-9 groundnuts produced at the Thai Department of Agriculture pilot oil extraction plant was employed as a protein source for snack foods. Pregelatinized tapioca starch was mixed with defatted groundnut flour and baking powder to prepare the snack base. The effects of different amounts of baking powder and pregelatinized starch on extension ratio, puffing ratio, bulk density, and compressive force of the snack base were investigated. The extension ratio and bulk density were not affected by the baking powder. It was concluded that a snack base composed of 33% defatted groundnut flour (300 g), 21% pregelatinized starch (190 g), and 46% water (420 g) should be used for developing the finished product.

Extruded snack food. This study was conducted at a factory in Thailand using a single screw extruder. The ingredients in the snack base were formulated by modifying the original formula used by the factory. The nutritious product, containing about 11% protein, was achieved by using defatted groundnut flour (19.8%), which resulted in the acceptability score of 7.8 (9 = liked very much).

The Philippines

In the Institute of Food Science and Technology, University of the Philippines at Los Baños, several studies have been conducted toward improving traditional Filipino groundnut products and developing new ones containing groundnuts. The following are examples of some of the products resulting from these studies. Garcia (1989) has reported on groundnut utilization in the Philippines.

***Yuba* (groundnut film).** The development of *yuba*, a protein- lipid film from groundnut milk, was investigated. Full-fat and partially defatted groundnuts were used in preparing milk. Deskinned groundnuts were soaked overnight in water at refrigerator temperature, then drained and weighed to determine the amount of water absorbed. Water was added to give a 1:6 (groundnut-water) ratio (w/v), and the mixture was ground in a blender for 5 min and filtered through a cheesecloth. The procedure was repeated to produce milk from 1:7, 1:8, and 1:9 (groundnut:water) ratios. Partial defatting was done by extraction of ground, deskinned groundnuts with hexane. The defatted groundnut was used to prepare milk from 1:8 and 1:10

groundnut-water ratios. Glycerol was added at a 2.5% level to milk before processing. Milks from a 1:6 full-fat groundnut-water ratio containing 0, 1.0, and 2.5% glycerol were also prepared.

Among the four full-fat formulations tested, the highest yield was obtained from milk prepared from a 1:8 groundnut-water ratio. A corresponding decrease in yield was observed as the amount of water was decreased. In the most diluted formulation, film formed only after concentration from prolonged heating, resulting in a very low yield. In contrast, partially defatted groundnut milk produced films when the processing temperature was reached. This would suggest the possibility of processing partially defatted milk of higher dilution than the formulations tested to obtain a higher yield of *yuba*.

Chemical analysis of films from partially defatted groundnuts gave a 1:6 fat-protein ratio compared with 2:1 ratio in full-fat films. This indicates the possibility of producing more stable films, in terms of rancidity, from a completely defatted groundnut milk.

Determination of physical and sensory properties revealed that an increase in glycerol level in the milk caused a corresponding decrease in the hardness and bitterness and an increase in breaking strength of films. In contrast, an increase in the amount of water in the milk formulation gave a decreased wet/dry tensile strength for both full-fat and partially defatted milk. In general, partially defatted films were stronger than full-fat films.

Groundnut nougat. Color and texture problems were encountered in the preparation of a groundnut nougat. Initially, the experimental nougat produced was darker than commercially available nougat, which is creamy white. This problem was corrected by adding cream of tartar to the formulation, which helped produce a vast improvement in the color of the end-product. It was observed that the bite property of nougat, which is initially sticky, became short upon storage. This phenomenon may be due to an incomplete dissolution of sugar in the syrup, which then crystallizes during storage. The corrective measure employed was to increase the temperature of the syrup, which brought about a browning reaction of sugar, thus, adversely affecting the color of the nougat. Further modification of the procedure to produce nougat with better color and texture is still necessary in order to be at par with or exceed the quality of commercially available nougat.

Collation of groundnut product formulations. Recipes of existing Filipino groundnut products have been compiled. The proximate composition of 10 different groundnut products was analyzed in 1989. The proximate composition of products differed because of differences in ingredients and processing methods. Groundnut 'kisses' had a low (1.93%) moisture content and *turon de maní* had the highest (10.91%) moisture content. Groundnut *adobo* (26.80%) and greaseless seeds (26.22%) had the highest protein content, while *panutsa* (local peanut brittle) had the lowest protein content (5.19%). Fat (44.67%) and ash contents (2.86%) were high in *adobo*. The 'kisses' contained 8.45% fat and *panutsa* contained 1.16% ash, which were found to be the lowest among the products analyzed.

Groundnut curd. Soft curd was prepared from roasted and blanched groundnuts. Various concentrations of firming agents ($CaCl_2$, $CaSO_4$, $MgCl_2$, and agar-agar) were added separately to groundnut milk, and the resulting curds were evaluated for flavor, aftertaste, texture, aroma, and acceptability. Among the firming agents added to groundnut milk, $CaSO_4$ was the most acceptable. No bitter taste was perceived in curds containing 2.5% and 5% concentrations. Bitter tastes were very perceptible in curds containing 2.5% $CaCl_2$ and $MgCl_2$. The bitter taste was much more perceptible with $CaCl_2$ than with $MgCl_2$ at 0.5%, which was the lowest concentration used. The addition of agar-agar (0.3%) to soft curd prepared using 0.5% $CaSO_4$ and $MgCl_2$ gave a good texture and consistency. Curd containing $CaCl_2$ and agar-agar had a definite bitter taste while curd containing $MgCl_2$ was slightly bitter. No bitter taste was noted when $CaSO_4$ was used as a firming agent. The use of agar-agar as a firming agent together with sugar resulted in an acceptable curd. Addition of 0.3 and 0.4% agar-agar produced a palatable soft curd that was comparable to conventional soft curd made from soybeans (*Glycine max*). The addition of sugar improved the flavor of soft curd by masking the strong raw groundnut flavor considered to be unacceptable. A sweetness resulting from 14–16° Brix improved the flavor of the curd. Roasting followed by steam blanching produced a flavor considered to be acceptable. Further improvements will be done in the process. Flavors will be added to enhance acceptability.

Fermented groundnut milk. Studies have been done in the Philippines to determine the suitability of groundnut milk as a substrate for bacterial fermentation. Fermented blanched groundnut beverage had a firm yogurt consistency, with syneresis occurring after 8 h fermentation. A high degree of syneresis occurred in fermented products made from roasted groundnuts after 24 h of fermentation. Syneresis was also observed in products prepared from groundnuts roasted at 85–100°C. A sandy texture was most evident in blanched groundnut yogurt.

Inoculation of groundnut milk with *Streptococcus thermophilous* resulted in a large decrease in pH from 6.03–6.75 to 5.1–4.50 after 8 h of fermentation. This was not true for groundnut milk inoculated with *Lactobacillus bulgaricus* where the decrease was gradual and minor from 4 to 24 h. An evident decrease in pH after 4 h of fermentation was observed for milk inoculated with *L. acidophilus*, *L. delbrueckii*, and *L. helveticus*. There was almost no change in pH and percentage lactic acid in groundnut milk inoculated with *L. helveticus* after 12 h of fermentation, In milks inoculated with *L. acidophilus*, pH decreased and percentage lactic acid increased throughout the 24-h fermentation period. For 'blanched' groundnut milk inoculated with *L. bulgaricus*, there was no significant decrease in pH and no increase in percentage lactic acid after 20 h of fermentation. Groundnut yogurt prepared using *S. diacetylactis* had a more desirable aroma than yogurts prepared using the other test cultures. While other yogurts retain the raw groundnut aroma and flavor, yogurt made using *S. diacetylactis* lacked this aroma and flavor. Generally, after 24 h of fermentation, an acid aroma masked the undesirably strong aroma in all fermented groundnut yogurts. The use of lactic acid bacteria to produce yogurt-like products from groundnuts is promising.

Groundnut sauces. The objectives of this study were to develop groundnut-based sauces acceptable to both children and adults, and to increase the shelf life of groundnut sauces. Two groundnut sauce formulations were developed. The first was based on an Indonesian sauce known as *gado-gado*. The other one was based on a Filipino concoction known as *lumpia*. The water activity (a_w) was 0.92 for groundnut sauce and 0.90 for *lumpia* sauce, the pH being 5.8 and 5.2. The goal was to bring the pH of the sauces to <4.5 so that they could be preserved with minimal heat processing, as high temperature and prolonged heating time would disrupt the groundnut emulsion, leading to poor sauce consistency. Sensory evaluation showed that 0.10% citric acid would be sufficient to achieve the desired acidity.

Taiwan

Groundnut products in Taiwan are extremely diverse. Salted and unsalted in-shell and shelled groundnuts, candies, confections, and peanut butter are the major forms consumed (Chiou 1989). These products are mostly home made or produced by small industries. Groundnut oil is one of the most important edible oils.

Groundnut vines, groundnut shells, and defatted groundnut meal are also utilized in Taiwan. Vines are used as green manure, fed to cattle, or combined with other vegetation to produce silage. Shells are used as fuel, or crushed and used in animal feeds, as mulch for nursery plants, as an absorbent in long-lasting fertilizer, and as a substrate for mushroom cultivation.

An extensive research program directed toward developing new uses for groundnuts and their byproducts continues at the Department of Food Processing at National Chiayi Institute of Agriculture. Basic and applied investigations of groundnut proteins, fermented products, and genetic engineering for the purpose of improving sensory qualities of groundnuts have excellent potential for success with the ultimate result of increasing per capita consumption of groundnut in Taiwan.

Indonesia

Groundnut consumption in Indonesia has increased, particularly since 1984 (Wirakartakusumah 1989). Data indicate that groundnuts contribute about 4% of the protein and 2% of the total calories consumed by Indonesians, based on an RDA of 2100 calories and 55 g of protein.

Most groundnut products are traditionally processed in home-scale industries. Salted groundnuts are popular. Freshly harvested pods are boiled in salt water and then sun dried or dried in hot sand. This process results in groundnut seeds with a unique crunchy texture that is considered to be a highly desirable characteristic by Indonesians, Malaysians, and many others in Southeast Asia.

Fresh unshelled groundnuts boiled in salt water are also consumed without drying. This method of preparation is also popular in the southeastern USA. Third-grade shelled groundnuts, coated with flour, tapioca starch, eggs, spices, and sometimes red dye are fried in oil to produce another popular product in Indonesia.

Oncom is a fermented groundnut presscake product particularly popular in West Java. Red *oncom* (*oncom merah*) is produced using *Neurospora intermedia* and black *oncom* (*oncom hitan*) is produced using *Rhizopus oligosporus*.

Groundnut sauce is accepted widely throughout Indonesia. Various types of groundnut-based formulations are used as dressings for salads and for *satay* prepared from chicken, beef, pork, or mutton. Consumption of *satay* sauce has increased in recent years due to the greater availability of *satay* in fast-food restaurants in the larger cities.

Malaysia

The majority of groundnuts produced in Malaysia are used for the production of an in-shell salted roasted product called *menglembu* (Zain and Azudin 1989). Low-grade seeds are mainly used as animal feed. Other food products include peanut butter, and coated and steamed groundnuts. About half of the peanut butter produced in Malaysia is exported to Singapore, Indonesia, and Brunei.

Menglembu is particularly popular among the Chinese in Malaysia, being consumed in highest quantities as a snack food during the Chinese New Year season. Consumption of *menglembu* and *ketupat* sauce made from raw groundnuts increases during the Hari Raya festival. The use of groundnuts in *satay* sauce for grilled chicken, mutton, beef, or their offals is also increasing. Malaysian *satay* sauce consists of ground roasted groundnuts, dried chilies, sugar, salt, water, and other seasonings. *Satay* sauce is also available in a convenient dried form.

Coated, fried groundnuts are a popular snack in Malaysia. Often the flour-egg batter used to coat the seeds contains spices as well as salt and sugar. Peanut butter produced in Malaysia is commonly made from seeds imported from the USA or China. Seeds that have been soaked in salt brine and then steamed or boiled are a popular snack sold by street vendors. Presscake resulting from oil extraction is sometimes used in biscuits and other food products.

Conclusions

There is great potential for the development of new groundnut-based products that will be widely accepted by Southeast Asians. Groundnuts can compete favorably with other legumes in terms of protein content and quality. However, calories, minerals, and general sensory quality (Chompreeda 1990) should receive increased consideration when new products are developed.

Details of developments of new groundnut-based products by the authors are included in annual reports of the Peanut CRSP. Copies of these reports can be obtained by writing to Dr D.G. Cummins, Director, Peanut CRSP, Georgia Experiment Station, University of Georgia, 528 Ivy Road, Griffin, Georgia 30223-1797, USA.

References

Chiou, R.Y.Y. 1989. An indigenous view of peanut utilization in Taiwan. Pages 60–70 *in* Trends in food product development: proceedings of the 7th World Congress on Food Science and Technology, Oct 1987, Singapore (Ghee, A.H., Yam, T.C., and Tan, C., eds.). Singapore: Singapore Institute of Food Science and Technology.

Chompreeda, P. (ed.) 1990. Proceedings, Training Course on Quality Evaluation and Utilization of Food Legumes and Coarse Grains, 1–26 Oct 1990, Bangkok, Thailand. Bangkok, Thailand: Kasetsart University.

Garcia, V.V. 1989. An overview of peanut utilization in the Philippines. Pages 21–26 *in* Trends in food product development: proceedings of the 7th World Congress on Food Science and Technology, Oct 1987, Singapore (Ghee, A.H., Yam, T.C., and Tan, C., eds.). Singapore: Institute of Food Science and Technology.

Haruthaithanasan, V. 1989. An overview of peanut utilization in Thailand. Pages 27–51 *in* Trends in food product development: proceedings of the 7th World Congress on Food Science and Technology, Oct 1987, Singapore (Ghee, A.H., Yam, T.C., and Tan, C., eds.). Singapore: Singapore Institute of Food Science and Technology.

Wirakartakusumah, M.A. 1989. Present status of peanut utilization in Indonesia. Pages 52–59 *in* Trends in food product development: proceedings of the 7th World Congress on Food Science and Technology, Oct 1987, Singapore (Ghee, A.H., Yam, T.C., and Tan, C., eds.). Singapore: Singapore Institute of Food Science and Technology.

Zain, A.M., and **Azudin, N.M.** 1989. The status of production and utilization of groundnuts in Malaysia. Pages 71–82 *in* Trends in food product development: proceedings of the 7th World Congress on Food Science and Technology, Oct 1987, Singapore (Ghee, A.H., Yam, T.C., and Tan, C., eds.). Singapore: Singapore Institute of Food Science and Technology.

Aspects of Groundnut Utilization and Possible Improvements of Indigenous Foods in Some Countries of Semi-Arid Tropical Africa

B. Singh[1]

Abstract

*Groundnut (*Arachis hypogaea*) is widely used in Sudan, Burkina Faso, Mali, Niger, Senegal, Nigeria, Gambia, and Ghana as a food source in a variety of forms. The most commonly utilized form of groundnut is the roasted seed, followed by ground seeds or paste (full-fat or partially defatted), groundnut oil, and raw or boiled groundnuts. Groundnut paste is used to prepare a deep-fried product,* kuli kuli, *in Nigeria.*

*Research has been conducted to improve the traditional method of roasting, grinding, and packaging of groundnut paste. The defatted groundnut flour has been used to improve the nutritional qualities of sorghum (*Sorghum bicolor*)-based indigenous foods such as* kisra, toe, *and the cassava (*Manihot *esculenta)-based product,* gari. *Peanut milk has been used to produce* mish, *a concentrated yogurt-like product.*

Résumé

Quelques aspects de l'utilisation de l'arachide et améliorations possibles de l'alimentation indigène dans certains pays africains des zones tropicales semi-arides: *L'arachide (*Arachis hypogaea*) est largement consommée sous bien des formes au Soudan, au Burkina Faso, au Mali, au Niger, au Sénégal, au Nigéria, en Gambie, et au Ghana. Le grain torréfié est la forme la plus fréquente d'utilisation, suivi par les grains pilés ou en pâte (avec toutes les matières grasses ou en partie dégraissée), l'huile d'arachide et les grains crus ou cuits à l'eau. La pâte d'arachide pilée sert à préparer un produit de grande friture, le* kuli kuli, *au Nigéria.*

*Des recherches ont été entreprises pour améliorer la méthode traditionnelle de torréfaction, du broyage et du conditionnement de la pâte d'arachide. La pâte d'arachide dégraissée a servi à améliorer les qualités nutritives de plats indigènes à base de sorgho (*Sorghum bicolor*) comme* kisra *et* toe *et à base de manioc (*Manihot esculenta*), le* gari. *Le lait d'arachide à également servi à produire du* mish, *produit concentré qui ressemble au yaourt.*

Groundnuts (*Arachis hypogaea*) are considered important as both an earner of foreign exchange and as a source of foodstuff in the semi-arid tropical (SAT) countries of Africa. However, very little has been documented about groundnut as a foodstuff except that it is widely used in Burkina Faso, Sudan, Senegal, Mali, Niger, Gambia, Ghana, and Nigeria in various forms (Cummins and Jackson 1982; Wheelock et al. 1989). In general, groundnuts are not available in these countries in refined or processed forms as they are in the USA. Also, groundnut meal, after the extraction of oil, is not well utilized in improving the

1. Formerly Professor and Peanut CRSP Coordinator, Peanut Collaborative Research Support Program (Peanut CRSP), Department of Food Science and Animal Industries, P.O. Box 264, Alabama Agricultural and Mechanical University, Normal, AL 35762, USA.

This paper was made possible through support provided by the Office of Agriculture, Bureau of Research and Development, U.S. Agency for International Development under Grant No. DAN-4-48-G-00-0041-000

Singh, B. 1992. Aspects of groundnut utilization and possible improvements of indigenous foods in some countries of semi-arid tropical Africa. Pages 257–263 *in* Groundnut – a global perspective: proceedings of an international workshop, 25–29 Nov 1991, ICRISAT Center, India (Nigam, S.N., ed.). Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

nutritional qualities of cereal or tuber-based indigenous foods. Groundnut utility is further limited due to the lack of postharvest technologies in storage and inventory management (Singh 1985, 1986). The role of groundnut as an earner of foreign exchange or as a cash crop has declined in many SAT countries due to aflatoxin contamination. Although very little attention has been paid to aflatoxin contamination in groundnuts for local consumption, it is a serious problem in Sudan, Burkina Faso, and Senegal (Singh, et al. 1989; Traore and Singh 1991; Pettitt, 1985).

This paper is based on research conducted under the Peanut Collaborative Research Support Program (Peanut CRSP) in Sudan and Burkina Faso on improvement of processing methods, utilization of groundnut in fortification of sorghum-based or cassava-based indigenous foods, and development of new groundnut based food products.

Products from Groundnuts

Groundnut is utilized in various forms in SAT countries including groundnut oil, roasted groundnut, boiled or raw groundnut and ground or paste. Data from a survey conducted in the Sudan indicated that the most commonly utilized form in Sudan was the roasted groundnut followed by groundnut paste, oil, boiled groundnut, and raw groundnut (Singh 1985). Roasted groundnuts are the preferred product in other SAT countries including Burkina Faso, Senegal, Gambia, Ghana, Mali, Niger, and Nigeria.

Roasted groundnuts

Groundnuts are roasted in the shell or as shelled seeds generally by stirring in hot sand in a flat-bottomed frying pot over a hot flame until they are well browned. The seeds are then separated by sieving from the hot sand. In the market place, groundnuts are roasted in small batches by vendors. The groundnuts are obtained from the market, sorted to remove broken, spotted, or moldy groundnuts. In one process, groundnuts, either unshelled or shelled with the skin intact, are roasted in hot sand. The unshelled groundnuts are shelled by hand and the skins loosened by rubbing with the hands and then removed by winnowing or blowing air. In a different method, the groundnuts are blanched in boiling water and then dried in the sun and roasted either in sand or ash. The roasted seeds in most cases are sold the same day. The shelf life of roasted groundnuts is rather short because no effective packaging materials are used. In addition, roasted groundnuts are not commonly available in the markets in urban areas in ready-to-use packages. In studies conducted at Alabama A&M University, USA, in collaboration with a Sudanese scientist, it was found that blanched roasted groundnuts packaged in glass jars maintained their qualities for a period of 3 months or more, as indicated by lower peroxide values.

Improvement of the roasting process is desirable from an aesthetic as well as economic viewpoint. Oguntunde (1987) suggested that roasting groundnuts by infrared heating, either unshelled or shelled, would facilitate the shelling process, in the case of unshelled groundnuts, and oil extraction, in the case of the latter. Thus, the traditional method of using sand as the medium for transferring heat to groundnuts by conduction could be replaced by infrared heating which would not involve the further step of separating the groundnuts from the sand particles after the roasting process.

Oil extraction

Industrial processing of oil from groundnut exists in Sudan, Senegal, Nigeria, and Gambia; however, oil extraction at the village level is quite common throughout the groundnut-growing countries of SAT Africa. For this process, roasted groundnuts are ground in a mortar to a smooth mash. The mash is kneaded and then squeezed to remove the oil. A small quantity of warm water is added to the mash following each pressing operation until as much oil as possible has been extracted (Oguntunde 1987). In a slightly modified method, the mash is heated with water and manually stirred. The separated oil is skimmed from the top. The process is repeated several times to extract the oil (Traore and Singh 1991). In general, the resulting cake contains about 20% fat.

Groundnut paste

One of the most commonly utilized forms of groundnut in Sudan, Burkina Faso, and other West African countries is partially defatted or full-fat groundnut paste. The partially defatted groundnut paste is produced after oil extraction. This may be used to make a deep-fried product called *kuli kuli* in Nigeria. In Burkina Faso, partially defatted paste is sold as *coura-coura* and used along with cereal or tuber-based products. It is also used as a meat-extender.

Normally, meat is covered with *coura-coura* before cooking. The composition of *coura-coura* and other groundnut products in Burkina Faso is presented in Table 1.

Full-fat groundnut paste is common in Sudan and in almost all West African groundnut-producing areas. In Sudan, the groundnut paste is prepared by certain groups of Sudanese in the home using the traditional method of roasting in sand, grinding with mortar and pestle (wooden), and then further grinding on a stone slab by cylindrical tools (such as bottles). The product is sold in the market wrapped in newspaper or in plastic bags. The product collected in 1983 was found to have a very high level of aflatoxin contamination. However, if the contaminated groundnuts are manually sorted, the contamination level could be reduced (Singh et al. 1989). The processes used in most West African countries are not very different from those in the Sudan.

These processes suggest several processing quality and efficiency concerns. It has been observed that considerable physical labor is required to process even a small amount of the paste. A hand-cranked or motorized plate-type attrition mill can be used as a more effective and rapid means of milling the roasted seeds into a spreadable consistency comparable with that obtained by the stone slab. These mills are relatively inexpensive in terms of construction and durability. Agbo et al. (in press) used a hand-cranked, plate-type attrition mill (Quaker City Mill, Philadelphia, PA, USA, Model 4-B) to grind the roasted groundnuts into a spreadable paste. The clearance between the plates could be adjusted to obtain the desired consistency of the groundnut paste (with minimal or nonexistent graininess). The paste was compared with the paste produced by the traditional method used in Sudan. The freshly milled paste had no apparent quality differences but later was found to have more metal contaminants and tended to be less shelf stable than the groundnut paste processed by the traditional method using stone grinding. The problem of lipid oxidation, however, could be minimized by packaging, temperature control, and by the addition of chelating agents. Recently, in Burkina Faso, groundnut paste has been processed and packaged by the Societé des huiles et savons du Burkina (SHSB) using batch processing. The groundnuts are sorted, graded, and then roasted before grinding to a smooth consistency similar to peanut butter. The product, packaged in 5-kg tin cans, is better in quality from both nutritional and safety considerations, compared to the products available in the market. The data in Table 2 indicate that there were variations in nutrient contents of pastes collected from various locations. The peroxide value in the SHSB product was lower than in the market samples, indicating the former being a more shelf-stable product. The aflatoxin and microbial contaminations in the SHSB paste were lower than those collected from local markets in various cities.

Utilization of Groundnut in Improvement of Cereal and Tuber-based Products

Groundnut oil cake (after extraction of the oil) is exported to European markets or used for human consumption in various ways throughout countries in SAT Africa. The partially defatted flour is used to improve the nutritional quality of various cereal-based products such as *gonfa*, a millet (*Pennisetum glaucum*)-based product, and *epo-ogi*, a corn (*Zea mays*)-based gruel. Acceptable *gari*, a commonly used cassava-based Nigerian food, can be prepared

Table 1. Approximate composition[1] and aflatoxin content of groundnut products consumed in Burkina Faso.

Product	Moisture (%)	Protein (%)	Fat (%)	Fiber (%)	Carbo-hydrates (%)	Aflatoxin B_1 (ppb)
Roasted groundnut (*marba tegui*)	4.4	22.8	46.8	0.21	18.2	24.7
Boiled sugared groundnut	5.6	13.2	42.1	1.7	49.1	18.9
Defatted groundnut paste (*coura-coura*)	6.91	33.0	21.2	0.4	24.0	29.0
Millet flour and groundnut paste mix (*gonfa*)	3.76	10.1	21.4	0.4	62.1	25.00

1. Values reported are means of eight replicates collected from the market place in Ougadougou in 1989.
Source: Traore and Singh 1991.

Table 2. Nutrient and aflatoxin contents in groundnut pastes sampled in Burkina Faso.

	Location				
	Banfora	Bobo-Dioulasco	Ouagadougou	Tenkodogo gog	SHSB[1]
Moisture (%)	0.8	1.0	1.1	0.9	0.8
Free fatty acids (as oleic acid) (%)	0.59	0.69	0.54	0.30	0.57
Fat (%)	51.3	47.9	49.2	50.3	51.6
Protein (%)	20.5	23.3	22.0	21.7	30.3
Carbohydrates (%)	25.1	22.3	24.3	23.3	15.2
Fiber (%)	1.7	1.5	2.3	2.4	2.2
Total ash (%)	2.6	2.7	2.5	2.5	2.6
Peroxide value (meg kg^{-1})	11.9	26.0	35.8	18.0	9.1
Aflatoxins (B_1) ppb	31.4	30.3	26.2	25.4	19.1

1. SHSB = Société des huiles et savons du Burkina.
Source: Traore and Singh 1991.

with 15% defatted groundnut flour. There was a fourfold increase in the amount of protein at this level of fortification, and a remarkable increase in the concentration of all the amino acids was observed (W.K. Kelker and D.R. Rao, personal communication).

Acceptable *kisra*, a sorghum-based food in the Sudan, was prepared using 30% defatted groundnut flour and 70% sorghum flour. There was a 73% increase in the amount of protein and 102% increase in the lysine content when fortified with groundnut flour at this level. Fortification and subsequent fermentation improved in-vitro digestibility and reduced the leucine/ isoleucine and the leucine/lysine ratios of composite flours (Table 3). A leucine/isoleucine ratio higher than 3.0 is considered to be deleterious.

Supplementation of sorghum flour with groundnut flour produced acceptable *toe*, a staple food in most parts of West Africa. A panel of nine African students familiar with *toe* quality tested sensory characteristics such as color, texture, taste, and general acceptability; the results indicated that *toe* can be prepared using as much as 30% groundnut flour (Tunde and Singh 1991). However, the sensory score for color, texture, and taste of sorghum *toe* was higher when only 15% groundnut flour was added. Higher levels of groundnut flour decreased the sensory score (Table 4). There was a significant increase in the amount of protein in *toe* and in composite flour by the supplementation of sorghum flour with groundnut flour.

Table 3. Ratios of amino acids as quality indices and in-vitro protein digestibility of *kisra* prepared from sorghum flour supplemented with groundnut flour.[1]

	Supplementation level (% defatted groundnut flour)					
Ratios	0	10	15	20	25	30
Leucine/isoleucine	5.7	5.1	4.3	3.1	3.1	2.7
Leucine/lysine	6.2	6.5	3.9	3.3	2.8	2.7
E/T[2]	2.7	2.5	2.5	2.4	2.2	2.1
In-vitro protein digestibility (%)	66.0	66.7	67.5	68.9	68.9	69.7

1. All values are means of three determinations.
2. Ratio of essential amino acids (E) to total amino acids (T).

Table 4. Sensory evaluation of the quality of toe prepared from sorghum flour supplemented with groundnut flour.[1]

Groundnut flour (%)	Sensory characteristics Color	Texture	Taste	General acceptability
0	3.9	3.7	3.2	3.4
10	4.2	4.2	4.4	3.7
15	4.2	3.9	3.8	3.9
20	3.5	3.2	3.1	3.0
25	3.9	3.0	2.7	2.7
30	3.4	2.8	3.0	3.0
35	3.2	2.8	2.8	2.4
SD[2]	0.39	0.56	0.61	0.54

1. Means of the scores of nine panelist using a rating scale of 5 = excellent, 4 = very good, 3 = good, 2 = poor, and 1 = very poor.
2. SD = Standard deviation.

Source: Tunde and Singh 1991.

Functional properties of the composite flour were determined (Singh and Singh 1991) and are presented in Tables 5 and 6.

Preparation of *Mish*-like Product

Mish is a concentrated, spiced yogurt prepared from whole milk in Sudan. It is usually consumed along

Shelled groundnuts

↓

Add groundnuts to boilling water, remove from heat and let soak for 7 minutes

↓

Drain, remove skins, soak the cotylendons in 2 % NaHCO overnight

↓

Rinse cotyledons with tapwater, blend in Waring blender with water (1:5 w/v) for 4 to 5 minutes

↓

Filter the homogenate through 4 layers of cheese cloth

↓

Add whey powder to the filtrate at 4 % level (w/v), mix throughly for 1 h and boil for 10 minutes

↓

Peanut Milk

Figure 1. Preparation of peanut milk.

Table 5. Water absorption, oil absorption, and emulsion capacity of groundnut flour (GF), sorghum flour (SF), and sorghum-groundnut composite flour (SGCF).[1]

Sample/treatment		Water absorption (g/g sample)	Oil absorption (g/g sample)	Emulsion capacity (g/g sample)	Emulsion capacity (g/g protein)
GF	Raw	1.18[a]	0.89[a]	24.5[a]	46.6[a]
	Boiled	1.70[b]	1.41[b]	18.0[b]	35.5[b]
	Roasted	2.53[c]	1.65[c]	23.9[a]	48.7[a]
SF	Raw	1.40[d]	1.63[c]	1.5[d]	15.8[c]
	Boiled	1.92[e]	2.24[d]	1.0[c]	11.4[d]
	Roasted	1.73[g]	2.05[d]	1.2[c]	14.1[ab]
SGCF	Raw	1.29[f]	1.57[c]	3.8[bc]	21.1[bc]
	Boiled	1.77[g]	2.35[d]	2.9[c]	16.4[c]
	Roasted	1.45[d]	1.78[c]	3.5[bc]	20.7[bc]

1. Means not followed by the same letters are significantly different from each other by the Duncan Multiple Range Test at the 0.05 level of probability.

Source: Singh and Singh 1991.

Table 6. Gelation capacity, viscosity, nitrogen solubility index (NSI), and protein dispersibility (PDI) of groundnut flour (GF), sorghum flour (SF), and sorghum-groundnut composite flour (SGCF).[1]

Sample/treatment		Gelation capacity (% flour)	Viscosity (peak ht B.U.)	NSI (%)	PDI (%)
GF	Raw	10.0^{a}	-	43.6^{a}	30.9^{a}
	Boiled	12.5^{b}	-	27.5^{b}	21.7^{b}
	Roasted	10.5^{a}	-	38.7^{c}	28.0^{c}
SF	Raw	5.5^{c}	630^{a}	16.1^{d}	9.8^{d}
	Boiled	8.0^{d}	438^{b}	10.7^{e}	7.3^{e}
	Roasted	7.5^{d}	525^{bc}	14.6^{bc}	9.5^{d}
SGCF	Raw	7.0^{ab}	405^{c}	22.6^{ab}	13.5^{ab}
	Boiled	9.5^{bc}	285^{d}	14.4^{bc}	11.6^{bc}
	Roasted	9.3^{bc}	302^{c}	20.0^{ab}	12.0^{bc}

1. Means not followed by the same letters are significantly different from each other by the Duncan Multiple Range Test at the 0.05 level of probability.

Source: Singh and Singh 1991.

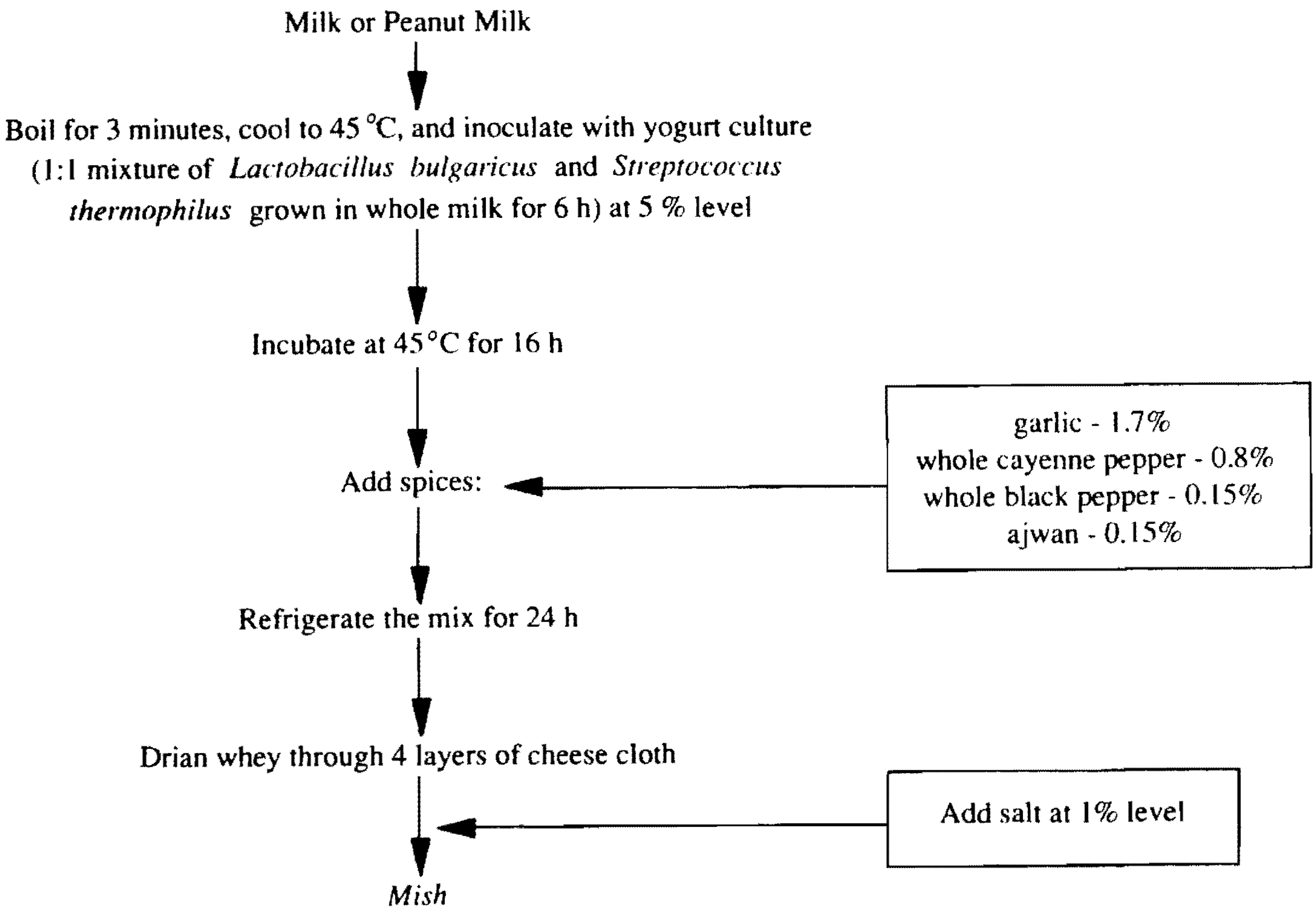


Figure 2. Preparation of *mish*.

with bread. Sensory evaluation of *mish* prepared from peanut milk, a 1:1 blend of peanut milk and whole milk, and whole milk did not show any difference in acceptability (Chawan et al. 1987). Methods for the preparation of peanut milk and *mish* are shown in Figures 1 and 2.

References

Agbo, F., Anderson, J.C., and **Singh, B.** (In press.) Peanut paste lipid oxidation by selected fractional factorial processing and storage environment parameters. Journal of Food Science.

Chawan, C.B., Rao, D.R., Singh, B., and **Muatine, R.** 1987. Preparation of Mish from peanut milk. Proceedings of American Peanut Research and Education Society 19:74.

Cummins, D.G., and **Jackson, C.R.,** (eds.) 1982. World peanut production, utilization and research. Special Publication no. 16. Athens, Georgia, USA; Georgia Agricultural Experiment Station.

Oguntunde, A.O. 1987. Production and possible improvement of Nigerian indigenous foods from grain legumes. Journal of Food and Agriculture 1:61-68.

Pettitt, R.E. 1985. Mycotoxin management in peanut by prevention of contamination and monitoring. Annual Report of the Peanut Collaborative Research Support Program (CRSP) 1984:86-119.

Singh, B. 1985. An interdisciplinary approach to optimum food utility of the peanut in SAT Africa. Annual Report of the Peanut Collaborative Research Support Program (CRSP) 1984:132-149.

Singh, B. 1986. An Interdisciplinary approach to optimum food utility of the peanut in SAT Africa. Annual Report of the Peanut Collaborative Research Support Program (CRSP) 1984:150-171.

Singh, U., and **Singh, B.** 1991. Functional properties of sorghum-peanut composite flour. Cereal Chemistry 68:460-463.

Singh, B., Khalid, A.S., Magboul, B., Okezie, B.O., Anderson, J.C., Wheelock, G.C., Jones, H., and **Caples, V.** 1989. Aflatoxin contamination of groundnuts with special reference to Sudan and some Caribbean countries. Pages 245-253 *in* Aflatoxin contamination of groundnut: proceedings of the International Workshop, 6–9 Oct 1987, ICRISAT Center, India. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Traore, A.S., and **Singh, B.** 1991. Evaluation of the quality of groundnut and groundnut products in Burkina Faso. Page 45 *in* Summary proceedings of the Second ICRISAT Regional Groundnut Meeting for West Africa, 11–14 Sep 1990, ICRISAT Sahelian Center, Niamey, Niger. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Tunde, K., and **Singh, B.** 1991. Studies on physicochemical properties and shelf-life of sorghum peanut composite flours for preparation of toe. Presented at the Annual Meeting, Institute of Food Technologists, 1-5 Jun 1991, Dallas, Texas, USA.

Wheelock, G.C., Jones, H.S., Singh, B., and **Caples, V.** 1989. Social science and food science research in Peanut CRSP. Pages 175-192 *in* The social sciences in international agricultural research: lessons from the CRSPs (McCorkle, C.M., ed.). Boulder, Colorado, USA: Lynne Rienner Publishers.

Discussion

Z.A. Chiteka: The high labor demand has been cited as a factor for decline in groundnut production in many areas. What is the cost of the Cecoco groundnut thresher that you mentioned? What efforts, if any, have been made to manufacture it locally?
M.S. Chinnan: The cost of importing a Cecoco thresher from Japan is US$ 4500, excluding shipping. A similar thresher manufactured and made available commercially in the USA is about US$ 6000. As the cost is high, we developed a simple, low-cost thresher; the cost in Belize is about US$ 3000, and it can be fabricated locally.

L.J. Reddy: The array of new groundnut products that have come in the market during the last 10 years is very impressive. As a breeder, I would be interested to know whether you have found cultivar differences as to their suitability for various groundnut products.
L.R. Beuchat: We have found significant cultivar differences for nutritional characters like fatty acid and amino acid profiles; flavor components vary not only between cultivars, but also within cultivars as influenced by growing conditions. But we are not merely looking at nutrition and flavor components. We are also interested in functional aspects like the physical behavior of partially defatted flour. Cultivar differences in chemical, physical, and nutritional characters are very important for developing a food product in the laboratory and for subsequent successful marketing of the product. It is very important for the food technologists and food scientists to work closely with plant breeders for the best return of the money invested in formulating a consumer product in any country. For example, in the USA, on an average it takes about 9 years to launch a prototype of the product as a successful commercial product; less than 1% of such products lasts for more than 2 years and this fact is often not realized by many people.
M.C.S. Sastry: Regarding new products of groundnut, I would like to add that the Central Food Technological Research Institute (CFTRI) in Mysore, India, has been doing considerable research on the processing, evaluation, and utilization of groundnut proteins and aflatoxin decontamination for the last 30 years. Technologies for the manufacture of weaning, geriatric, and breakfast foods, edible quality flour, and protein isolates have been made available for commercial exploitation. The most recent product is partially defatted groundnut seeds having 6.5% fat content.

M.P. Ghewande: What biocontrol agents are used in managing the aflatoxin contamination in groundnut products? To what extent are these biocontrol methods successful?
V.V. Garcia: We have isolated two molds that control or inhibit the growth of *Aspergillus flavus*. At the moment, we are trying to use these molds in such a way that there is no production of aflatoxin in the groundnut products by toxigenic fungi.

S. Drammeh: Is there a simple method that could be used by consumers at the village level to reduce the level of aflatoxin present in peanut butter?
B. Singh: There is no simple method available yet to decontaminate groundnut meal with aflatoxins. However, we have found that if fungus-infected groundnut seeds are manually removed prior to roasting and grinding, the aflatoxin levels could be substantially reduced in the final product.

Implementation of Integrated Pest Management in Groundnut: Current Status and Future Direction

R.E. Lynch[1] and G.K. Douce[2]

Abstract

*Integrated pest management (IPM) evolved from the 'integrated control' and 'insect scouting' philosophies of the late 1950s and early 1960s. It is based on an ecosystem approach to pest control with the biosphere as the system of concern. The concepts of economic-injury level and economic threshold along with scouting to determine insect density are the cornerstones for effective IPM. Approaches to insect control for implementation in an IPM program include physical, cultural, host plant resistance, biological, and chemical methods. Examples are presented of these approaches currently used to manage groundnut (*Arachis hypogaea*) insects in both developing and developed nations. A summary of the National Evaluation of Extension's Integrated Pest Management Program for groundnut is presented to illustrate the role of extension in implementation of an effective IPM program. Future approaches that will be used in pest management include dynamic predictive models integrating production, pests, and cost variables, genetically engineered plants and control organisms, multiple pest-resistant cultivars, altered social insect pest communities, and the managed manipulation of entomophages.*

Résumé

Application de la lutte intégrée contre les ennemis de l'arachide—bilan actuel et orientation à venir: *La lutte intégrée contre les ennemis est née des philosophies de "la maîtrise intégrée" et de "la surveillance des insectes" des dernières années 1950 et des premières années 1960. Elle est basée sur l'approche écosystème de la lutte contre les ennemis qui se préoccupe de la biosphère. Les concepts du niveau pertes économiques et du seuil économique, ainsi que la recherche pour déterminer la densité des insectes, sont les pierres angulaires d'une lutte intégrée efficace. Les approches à la lutte contre les insectes en vue d'application dans un programme comportent des méthodes physiques, culturales, de la résistance du plant hôte, biologiques et chimiques. Des exemples sont présentés de ces approches actuellement utilisées contre les insectes de l'arachide (*Arachis hypogaea*) dans les pays en développement et les pays développés. Un résumé de l'évaluation nationale du programme de lutte intégrée contre les ennemis pour l'arachide est présenté pour illustrer le rôle de la vulgarisation pour l'application d'un programme efficace. Des approches ultérieures qui serviront à la protection de la culture comprennent des modèles prédictifs dynamiques intégrés à la production, aux ennemis et aux variables du coût, des plants et des organismes témoins issus de génie génétique, des cultivars résistants à de multiples ennemis, des communautés modifiées d'insectes sociaux et la manipulation surveillée des entomophages.*

1. Supervisory Research Entomologist, Insect Biology and Population Management Research Laboratory, USDA-ARS, P.O. Box 748, Tifton, GA 31793-0748, USA.
2. Extension Entomologist, Cooperative Extension Service, Department of Extension Entomology, University of Georgia, Tifton, GA 31793, USA.

This paper was made possible through support provided by the Office of Agriculture, Bureau of Research and Development, U.S. Agency for International Development under Grant No. DAN-4048-G-00-0041-00.

Lynch, R.E., and **Douce, G.K.** 1992. Implementation of integrated pest management in groundnut: current status and future direction. Pages 267–278 *in* Groundnut – a global perspective: proceedings of an international workshop, 25–29 Nov 1991, ICRISAT Center, India (Nigam, S.N., ed.). Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Integrated pest management (IPM) evolved from the 'integrated control' and 'insect scouting' philosophies that were emphasized in the late 1950s and early 1960s (e.g., Stern et al. 1959; Boyer et al. 1962; Lincoln et al. 1970) when it was realized that pest control practices based primarily on the use of synthetic organic chemicals could not be sustained. Metcalf and Luckman (1975) defined IPM as the intelligent use of pest control action that will insure favorable economic, ecological, and social consequences. IPM is not an entity by itself; rather, it is part of a system integrating agronomy, entomology, plant pathology, weed science, and other appropriate disciplinary approaches to crop production (Douce et al. 1983). Aside from the idealized intellectual and esoteric goals of IPM, the driving force behind a producer adopting and using IPM, whether in high or low technology areas, is the desire to obtain adequate pest control while maximizing net profit and minimizing production costs (Musser et al. 1986).

IPM principles are based on an ecosystem approach to pest control. The ecosystem of concern must include the earth as a whole since the effects of IPM may be far reaching, just as fluorocarbons have possibly influenced ozone depletion and global warming. IPM practices must encompass considerations not only for the crop pest(s) in question, but also for other organisms and environmental factors in the ecosystem surrounding a crop. Ecosystems are self-sustaining where living organisms and the nonliving environment interact to exchange energy and matter in a continuing cycle (NAS 1969). Even though a production area under consideration may represent only a small part of the total ecosystem, scientists who develop an IPM system and producers who use these approaches must integrate them into a total production and management system. Both IPM specialists and producers must understand the ecosystem and the potential consequences of their management decisions if IPM is to be successfully implemented. This responsibility places a tremendous burden on those attempting to implement new IPM technology to insure that adequate education and information are provided to the intended user of the technology.

Central to the theme of IPM are the concepts of economic-injury level (EIL) and economic threshold (ET). Stern et al. (1959) defined these as follows: the EIL is the lowest pest population density that will cause economic damage, i.e., damage with a monetary value greater than the cost of control. An ET is the pest density at which control measures are initiated to prevent an increasing pest population from reaching the EIL. The ET is lower than the EIL to permit sufficient time for the initiation of action that will reduce the pest population before it reaches the EIL. The ET and EIL are not static but constantly fluctuate with the stage of plant growth, the price received for the crop, and the cost of control. Sampling to determine pest density in relation to the developmental stage of the crop is also a cornerstone for IPM. Thus, the EIL and ET must be reasonably and realistically determined before an IPM program based on pest sampling can be developed.

An often neglected but important factor in IPM programs in groundnut (*Arachis hypogaea*) is that several pests are nonspecific to groundnut and are capable of not only local, short distance movement, but also of long-distance passive or actively assisted movement in conjunction with meteorological events (Hatfield and Thomason 1982). Long-distance movement and host succession extend the consideration for pest management beyond what is normally considered as local ecosystem boundaries. Hence, pest management in many instances must be based on an understanding of pests and their management on different host sequences, and may entail an area-wide approach to pest management.

IPM Approaches and Implementation

Recent reviews by Lynch et al. (1986), Wightman and Amin (1988), and Wightman et al. (1990) have identified the major economic pests of groundnut in the USA, Asia, and Africa (Table 1). Various approaches are available for implementation in an IPM program for management of these insects. These approaches include host plant resistance, physical, cultural, biological, and chemical methods of control. Excellent reviews of the use of these approaches for managing individual insect pests of groundnut are found in Smith and Barfield (1982) and Wightman et al. (1990). Selected examples of approaches used to manage insect populations in groundnut IPM programs will be presented here.

Physical control

Physical control uses direct and indirect methods to kill insects by means other than insecticides: e.g., hand picking, light traps, barriers, etc. Examples of the use of physical control in groundnut IPM include community involvement in reducing populations of white grub adults by destroying adult beetles during the evening while they are above ground feeding and

Table 1. Major arthropod pests of groundnut[1].

Feeding site	Insect species		
	USA	Asia	Africa
Foliage	*Frankliniella fusca* (Hinds) *Empoasca fabae* (Harris) *Helicoverpa zea* (Boddie) *Spodoptera frugiperda* (J.E. Smith) *Feltia subterranea* (F.) *Anticarsia gemmatalis* (Hübner) *Tetranychus urticae* Koch	*Thrips palmi* Karny *Frankliniella schultzei* (Trybom) *Scirtothrips dorsalis* (Hood) *Caliothrips indicus* Bagnallith) *Spodoptera litura* (F.) *Empoasca kerri* Pruthi *Helicoverpa armigera* (Hübner) *Aproaerema modicella* (Deventer) *Aphis craccivora* Koch *Amsacta* spp	*Aphis craccivora* (Koch) *Empoasca facialis* Jacobi *Empoasca dolichi* Paoli Thrips (several species) *Helicoverpa armigera* (Hübner) *Spodoptera littoralis* (Boisduval)
Root, peg, or pod	*Diabrotica undecimpunctata howardi* Barber *Elasmopalpus lignosellus* (Zeller) *Conoderus sissus* Schaeffer	*Odontotermes* sp *Microtermes* sp *Lachnosterna consanguinea* (Blanchard) *Anisolabis stali* (Lucas) *Dorylus orientalis* Westwood	*Microtermes thoracalis* Sjostedt *Hilda patruelis* Stal. *Caryedon serratus* (Ol.) Whitegrubs (numerous species) *Peridontopyge* sp *Elasmolomus sordidus* (F.)

1. Modified after Amin and Mohammad (1980), Lynch et al. (1986), Wightman et al. (1987), and Wightman et al. (1990).

mating (Brar and Sandhu 1980). The removal of volunteer groundnut plants early in the season also has been mentioned by several authors as a method for controlling insects or insect-borne diseases. Bass and Arant (1973) suggested this practice to prevent infield population increases of thrips prior to sowing. Similarly, the removal of volunteer groundnut plants and destruction of alternative weed hosts for *Aphis craccivora* to reduce sources of groundnut rosette virus (GRV) have been suggested (Davies 1972; Kousalya et al. 1971; Gibbons 1977).

Wightman et al. (1990) reported that farmers in India grow castor plants in groundnut fields to attract ovipositing *Spodoptera* moths. The moths preferentially lay eggs on the leaves of castor where the eggs or larvae are easier to find and destroy.

Cultural control

Cultural control includes production practices that make the environment less favorable for survival, growth, or reproduction of insect pests, and includes manipulation of sowing and harvest dates, tillage operations, crop rotation, irrigation, and sanitation. Cultural control probably represents the most widely used IPM tactic worldwide. Aphids, primarily *A. craccivora*, are important pests both from the direct damage caused by their feeding and from their ability to transmit viral diseases such as rosette. Increased plant populations and early sowing reduce aphid populations and the incidence of GRV (Farrell 1976a, 1976b; Davies 1972). Hull (1964) suggested that lower plant populations were more attractive to immigrating adult aphids due to an increase in yellow, a color that enhances the alighting response of *A. craccivora*. New terminals and leaves are more yellow than older foliage and are more abundant and more exposed on plants of low population densities. Farrell (1976b) also demonstrated that the rate of increase for aphids is lower on closely spaced plants. Thus, close sowing reduces initial incidence of GRV and its secondary spread.

Thrips, primarily *Frankliniella schultzei* and *Thrips palmi* Karny in Asia and *F. fusca* and *F. occidentalis* in the USA, are important vectors of tomato spotted wilt virus (TSWV), the causative agent for bud necrosis disease. Amin and Mohammad (1980) reported a lower incidence of TSWV as a result of higher plant populations and early sowing. Yield loss due to TSWV is generally lower in densely sown crops than in sparsely sown crops (Wightman and Amin 1988). This relationship among sowing date, plant population, and incidence of TSWV has not been confirmed in the USA (J.W. Todd and J.R. Chamberlin, personal communication).

Smith and Barfield (1982) reported that groundnut is most susceptible to defoliation from 70–80 days postemergence but practically immune to yield loss from defoliation prior to bloom initiation and near harvest. Thus, manipulation of groundnut sowing dates is a viable means for reducing potential losses due to major defoliators in the southeastern USA. The corn (*Zea mays*) earworm (CEW), *Helicoverpa zea*, is an annual pest of groundnut, particularly in the southeastern USA. Corn is the primary host of the CEW during the early growing season (Wiseman and Davis 1990). Tremendous adult populations of CEW arising from infestation of ear stage corn emerge during late July and August and are attracted to crops such as groundnut, soybean (*Glycine max*), and cotton (*Gossypium* spp), which are in a more attractive stage of plant development. Groundnut sown in early to mid-April have passed their most susceptible growth stages for yield loss during periods of peak populations of the CEW in late July and August.

Altering the sowing date also has been suggested as an approach for reducing damage in groundnut by the lesser cornstalk borer (LCB), *Elasmopalpus lignosellus*, in the USA. Leuck (1967) noted that groundnut sown prior to mid-April in the southeastern USA usually escapes damage by the LCB. Smith and Barfield (1982) also suggested that groundnut sown in May in Texas should escape damage by LCB when populations reach a peak in mid-August. LCB larvae prefer and damage immature groundnut pods (stages 1–3) prior to the development of structural rigidity in the mesocarp more than more mature pods (stages 4–7) (Lynch 1984). As with most insect pests of groundnut, LCB populations tend to be lowest during the early part of the growing season and increase as the growing season progresses. In most years, damaging populations of the LCB occur during the latter part of the groundnut growing season. Thus, early-sown groundnut would have a greater percentage of pods in stages 4–7 in August and September than would late-sown groundnut and would be less preferred and less susceptible to LCB damage than late-sown groundnut.

In West Africa, termites are important pests of groundnut (Lynch et al. 1986; Wightman et al. 1987, 1990). These insects may invade the tap root or lateral branches of the plant resulting in plant death, may damage pods by externally scarifying the pod surface, or may penetrate the pod and feed directly on the seed. Adjusting the groundnut sowing and/or harvest date is a viable strategy for reducing termite damage to groundnut plants and pods, especially in regions that have a definite rainy and postrainy season. In West Africa where groundnut is grown, seasonal rain begins along the southern coast and progresses northward. Growing seasons range from 75 days with 500–900 mm of rain in northern areas to almost 150 days with 1000–1650 mm of rain in the southern areas. Termite damage to pods tends to be more extensive during the latter portion of the growing season, especially during periods of inadequate rainfall (Feakin 1973; Johnson and Gumel 1981). Sowing an appropriate variety of groundnut with a length of maturity that corresponds with the length of the rainy season is an important method for preventing late-season damage to pods by termites. Lynch et al. (1990) reported that only a 2-week delay in harvesting groundnut was sufficient to increase termite damage to pods by over 50%. Data collected at the Gampala Research Station in Burkina Faso showed that pod damage due to termites was negligible through 90 days, increased slightly by 110 days, and increased substantially by 125 days (Table 2). A similar increase in aflatoxin in seed was also noted. Thus, much termite damage to groundnut pods can be avoided by ensuring a proper match between groundnut maturity, length of the growing season, and timely harvesting at the end of the growing season.

Wightman et al. (1990) suggested that farmers may be able to reduce populations of termites over time by incorporating plant residue into the soil, composting the residue, burning the residue (as a last resort), and mechanical cultivation to destroy the termitaria and underground tunnels. Feakin (1973) also noted that mechanical cultivation over successive years may reduce termite populations and, thus, reduce damage.

Host plant resistance

Plant resistance to insects has shown tremendous potential for the management of several insects that damage groundnut and was recently reviewed by Lynch (1990). The use of plants with insect resistance to alleviate production losses is especially appropriate for developing countries and for insects that transmit diseases, since, once developed, the use of a variety is without cost to the farmer.

Excellent sources of resistance in groundnut to the potato leafhopper, *Empoasca fabae*, in the USA, and *E. kerri* in India, have been reported (Campbell et al. 1971, 1975, 1976; Amin and Mohammad 1980; Amin et al. 1985). All three mechanisms of resistance to

Table 2. Effect of age of groundnut at harvest on termite damage to pods, yield, and aflatoxin in seeds in Burkina Faso, West Africa.

Groundnut age at havest (days)	Termite-damaged pods[1] Undamaged (%)	Scarified (%)	Penetrated (%)	Aflatoxin[2] (ppb)	Yield[1] (g plot^{-1})
70	98.4	0.4	1.2	27.1	4068.3
90	97.3	1.3	1.4	122.7	5419.3
110	84.9	11.8	3.3	680.3	5140.7
125	54.0	39.5	6.8	1246.2	4466.6
Insecticide control[3]	90.0	7.7	2.4	842.7	5957.5

1. Means based on 5 years' data, 1986–1990.
2. Means based on 2 years' data, 1987 and 1988.
3. Plots treated with 5.6 kg ha^{-1} aldicarb at sowing, 7.5 kg ha^{-1} chlorpyrifos at pegging, and 7.5 kg ha^{-1} chlorpyrifos 50 days later for insect control.

leafhoppers have been reported (Lynch 1990). Nonpreference resistance is associated with a thick leaf epidermis, long trichomes on the lower epidermis, and a higher percentage of straight trichomes; more susceptible lines have either curved trichomes or an appressed surface texture on their leaves (Campbell et al. 1976). Antibiosis resistance is expressed as reduced fecundity by leafhoppers feeding on resistant genotypes (Campbell and Wynne 1980; Amin 1985a). Tolerance to feeding by leafhoppers expresses as resistance to the damage symptoms, e.g., yellowing of the leaf tips was reported in several lines which support intermediate populations of leafhoppers, but did not produce symptoms that other lines showed with similar populations of leafhoppers (Amin et al. 1985).

TSWV has been a major concern in Southeast Asia for years, but it is relatively new as an important disease of groundnut in the USA. In India, resistance to thrips and TSWV has been identified in acceptable commercial cultivars. Robut 33-1 is a high-yielding cultivar that has resistance to thrips and field resistance to infection with TSWV (Amin and Mohammad 1980; Amin 1985b). ICGS 11, ICGS 44, and ICGS 1 selections from Robut 33-1 were released by ICRISAT and have improved agronomic characteristics as well as resistance to TSWV (Wightman et al. 1990; Nigam et al. 1991). In the USA, Southern Runner has been shown to have a lower incidence of TSWV than Florunner, the most commonly sown groundnut variety (Culbreath et al. 1990; Culbreath et al. 1992).

The development of groundnut cultivars with resistance to rosette, a virus disease transmitted by *A. craccivora*, has been an important aspect of breeding programs in Africa (Gibbons and Mercer 1972). Several cultivars, KH-149 A, KH-241 D, RMP 12, RMP 91, RG 1, RRI/6, and 69-101, with resistance to rosette have been developed and released for commercial production or use in breeding programs (Bockelee-Morvan 1983; Nigam 1987). RMP 12, RMP 91, KH-149 A, and KH-241 D are commonly sown in West Africa where rosette is a problem.

Several lines have been reported with resistance to multiple pests. Amin et al. (1985) reported resistance to the leafhopper, *E. kerri*, the thrips, *F. schultzei*, and termites of the genus *Odontotermes*; several of the reported genotypes had resistance to more than one pest. Probably the best example of a groundnut variety with multiple pest resistance is NC 6, a large-seeded virginia variety grown in the Virginia-Carolina area of the USA that is resistant to the southern corn rootworm, *Diabrotica undecimpunctata howardi*, moderately resistant to the potato leafhopper and corn earworm, and slightly resistant to the tobacco thrips, *F. fusca* (Campbell et al. 1977; Campbell and Wynne 1980, 1985). Resistance in NC 6 resulted in the use of 60–80% less insecticide for rootworm, leafhopper, corn earworm, and thrips control than was required for controlling these insects on Florigiant (Campbell and Wynne 1985).

Biological control

Biological control is the most important mechanism regulating insect populations. Without parasites, predators, and disease organisms, most pests would reach or exceed the EIL much more often, if not during every pest generation. Key components of biological control include importation and release of exotic species, augmentation of existing biological control agents, and conservation of natural enemies (Batra 1982). In groundnut ecosystems, only conservation of natural enemies through the use of IPM is presently employed to any major extent as a biological control strategy.

Biological control of two pests of groundnut in the USA illustrates its usefulness in managing populations of pest species. The CEW, as previously noted, is one of the major defoliators of groundnut in the USA. Life table research conducted to determine the fate of eggs and larvae of the corn earworm infesting groundnut in Texas showed that its population density is usually held below the EIL by parasites, predators, and diseases (Sears and Smith 1975). Real mortality for CEW eggs and larvae for all generations ranged from 74.32 to 99.97%, averaging 96.3%. Egg mortality was significant, ranging from 45 to 93%, as was larval mortality, ranging from 5 to 50%. *Trichogramma* parasitized from 3 to 83% of the CEW eggs, and its rate of parasitism increased with each CEW generation. Larval mortality was primarily due to parasitism, mainly by *Microplitis*, and microbial infection with a nuclear polyhedrosis virus (NPV). Larval populations of the CEW peaked in late July and early August, and then declined as they became infected with the NPV. Once during the study, larval populations peaked at around 32.8 larvae/m of row, but no artificial control was applied. The larvae were heavily parasitized by *Microplitis*, which generally emerge from CEW larvae during the fourth and fifth instar, prior to major defoliation by the host. Thus, natural biological control of the CEW maintained populations below the EIL.

A similar scenario has been noted for the CEW in the southeastern USA (Lynch, unpublished). Low population densities of the tobacco budworm (TBW), *Heliothis virescens*, and CEW in groundnut are first noted during early to mid-July. If left untreated, the majority of these larvae become infected with an NPV. Infected larvae crawl to the top of a plant and, upon death, liquify, and rupture, dispersing millions of viral particles over the foliage. The virons will be further dispersed by dew, rain, and other insects that come into contact with the particles from the cadaver. Generally, in fields in which the viral epizootic is allowed to complete its natural cycle, subsequent generations of the CEW rarely reach the EIL. However, many groundnut growers in the Southeast treat subeconomic infestations of defoliating insects by tank-mixing an insecticide with fungicide during routine treatment for control of leaf spot. This process disrupts the natural control process, killing parasites, predators, and pest larvae that are either diseased or parasitized. As a result of this disruption in natural control processes, treated fields are much more likely to develop economic infestations during subsequent generations of the CEW.

The second example is the biological control of the lesser cornstalk borer, a key pest of groundnut in the southeastern and southwestern USA. A 3-year study showed that total generational mortality for the LCB in groundnut in Texas ranged from 87.1 to 99.9% (Johnson 1978; Smith and Barfield 1982). Highest mortality, 49.7 to 86.8%, was recorded for eggs and newly hatched larvae with over 60% mortality of third and fourth instar larvae. They noted that LCB mortality was independent of its density, suggesting that abiotic rather than biotic factors were regulating its populations.

In sandy soil, LCB eggs are generally laid and larvae feed just below the soil surface (Smith et al. 1981; Leuck 1966). During periods of high soil moisture, a higher percentage of LCB eggs and larvae are found on the plant or soil surface where biocontrol agents are more effective in regulating their populations (Carolla 1984). However, under hot, dry conditions that are conducive to outbreaks, LCB are more cryptic and not as readily accessible to predation or parasitization. Furthermore, LCB larvae, pupae, and adults are much better adapted to the hot, dry conditions (Mack and Appel 1986) than are their natural enemies (Mack et al. 1988). The cuticular permeability of the LCB is similar to that of desert arthropods, and much lower than the cuticular permeability of its primary predators. Thus, under environmental conditions that favor endemic populations of the LCB, e.g., adequate rainfall and moderate soil temperature, natural enemies play an important role in the regulation of LCB populations. Conversely, during drought, the groundnut plant folds its leaves during the day to conserve moisture, exposing the soil below groundnut plants to more direct solar radiation which drastically increases soil temperature. Under the latter conditions, the LCB survives better than its predators and probably other biocontrol agents; as a result, natural control of the LCB population fails and outbreaks occur (Mack et al., in press).

Chemical control

Chemicals used in IPM programs include not only insecticides but also a variety of other compounds, such as pheromones, repellents, attractants, and chemosterilants. Insecticides have been and will continue into the foreseeable future to be one of the primary control measures for assisting in the regulation of insect populations. In groundnut systems, insecticides have been extensively employed both preventatively and within the precepts of IPM in the management of insects. The entomological literature of groundnut is replete with the effectiveness of insecticides in reducing pest populations and increasing groundnut yield. Excellent treatises on the use of insecticides in groundnut IPM are presented by Smith and Barfield (1982) and Wightman et al. (1990). Over the past several years, major advances in the use of insecticides for management of insects have been the development, recommendation, and use of more selective insecticides that have fewer detrimental effects on nontarget beneficial species.

Pheromones for several important lepidopterous pests of groundnut have been identified and are employed to monitor populations. An excellent example of the use of pheromones to monitor insect populations is being conducted by the Cooperative Extension Service of the University of Georgia. Pheromone traps for the CEW, TBW, fall armyworm, *Spodoptera frugiperda*, and beet armyworm, *S. exigua*, are routinely monitored during the growing season in several key areas of Georgia. Results showing trap captures per night for the key locations are published weekly in the *Pest Survey Update Newsletter* and are sent to all county extension agents and other interested subscribers. Thus, county extension agents are aware of the potential for outbreaks for these pests as measured by pheromone traps and are able to alert growers and scouts when populations increase to a potentially threatening level.

Scientists at ICRISAT are developing a prediction model for *Spodoptera litura* based on pheromone trap data (Wightman et al. 1990). Data on yield losses as a result of different levels of larval infestation of this insect during seedling, flowering, pegging, and pod formation stages of groundnut have been generated to establish EILs for both the rainy and postrainy growing seasons. Preliminary data suggest that treatment may be effective in reducing armyworm damage when applied 6 days after pheromone traps capture 50 or more males per trap for more than 3 nights or when crop inspection reveals more than three egg masses (meter of row)$^{-1}$.

Evaluation of Groundnut IPM in the USA

Extension specialists with the University of Georgia, Cooperative /Extension Service, in cooperation with the network of county extension agents in Georgia, provide an excellent example of IPM implementation. A team of groundnut extension specialists consisting of two agronomists, an entomologist, a plant pathologist, an economist, a weed scientist, a soil scientist, an agricultural engineer, and an IPM specialist is located in the major groundnut production area of the state. These specialists provide information to groundnut growers through the network of county extension agents. Information is provided through grower meetings held at various locations throughout the groundnut growing region of the state, numerous extension pamphlets, a pest control handbook, a groundnut scout handbook, a publication entitled, 'Peanut pest management in the southeast,' a groundnut shortcourse, a scout training school, several pest management workshops exclusively for county agents, field days, and an IPM newsletter (*Pest Survey Update*).

An evaluation of the 1981 Georgia IPM program showed that groundnut yield for growers that participated in the IPM recommendations averaged 4010 kg ha^{-1} compared with a yield of 3158 kg ha^{-1} for nonparticipants, representing a 27% yield increase for participants (Douce 1982). The IPM program did not result in use of less chemical, as might be expected. In fact, participants' average cost for chemicals was US$ 229 ha^{-1} compared with US$ 206 ha^{-1} for nonparticipants. Gross returns averaged US$ 996 ha^{-1} and US$ 790 ha^{-1} and net returns averaged US$ 445 ha^{-1} and US$ 365 ha^{-1} for participants and nonparticipants, respectively. Extrapolated to a statewide basis, the increase in net return translates into a nearly US$ 6.6 million total benefit for Georgia groundnut producers in 1981 who utilized IPM.

In 1983, a national evaluation of Extension's Integrated Pest Management Program was conducted. The evaluation of the groundnut IPM program was conducted in Georgia and was designed to examine the current status and effectiveness of the Extension Integrated Pest Management Program for groundnut (Rajotte et al. 1987). For analysis purposes, clientele were divided into three groups, nonusers, low users, and high users based on their adoption of IPM procedures and recommendations. Differences among these groups were substantial and can be summarized as follows:

- High and low users reported higher yields and higher positive net returns than did nonusers.
- Per hectare costs for pesticides were greater for nonusers (US$ 121) than for low users (US$ 94) or high users (US$ 108).

- High and low users had slightly higher total pest management costs, primarily due to costs for scouting, than did nonusers.
- Per hectare net return was greater for high users (US$ 263) and low users (US$ 147) than for nonusers (US$ 81).

The respondents to the IPM survey indicated that their major source for pest management information was as follows: 96.8% obtained information from county extension agents, 94.7% from extension production meetings, 91.5% from extension publications, and 82.4% from extension specialists. When asked their reasons for participating in IPM, 97.4% indicated improvements in yield and quality, 95.4% indicated better pest control, and 92.7% indicated increased profits. Other reasons noted by a high percentage of the respondents were safe use of pesticides, reduction of environmental damage, better use of natural enemies for pest control, and reduced personal hazards. In general, a higher percentage of high users and low users were concerned about safe use of pesticides, natural enemies, and the environment than were nonusers.

Growers felt that the system of county extension agents, extension specialists, and meetings, training, and publications generated by extension were important in their IPM programs. Over 94% classified extension agents and/or extension production meetings as a useful or very useful source of pest management information. A higher percentage of high users (93.1%) and low users (95.4%) thought that extension publications were useful or very useful for pest management information. Similarly, a higher percentage of high users (86.3%) and low users (84.7%) classified extension specialists as important sources of pest management information than did nonusers (70.5%).

Grower acceptance of IPM was also indicated in their utilization of IPM practices. High users (80.3%) utilize the scouting practice of counting pests more than low users (72.1%) or nonusers (61.8%). Similarly, high users (80.8%) attempted to distinguish beneficial from pest insects more than low users (73.8%) or nonusers (64.7%). High users (97.3%) also selected pest management materials based on the scouting report more than low (90.1%) or nonusers (59.2%). A greater percentage of the high users than low or nonusers also considered the use of natural enemies for pest control and the reduction of environmental damage to be a very important reason for adopting IPM practices. Other important implications from the study of the peanut pest management program include:

- The growers most likely to use IPM are better educated and have more recently established large farming operations.
- Scouting was the most frequently used IPM technique, followed by crop rotation.
- A greater percentage of high users made the decision to use insecticides based on ETs, selected the material to spray based on scouting reports, and were more flexible from field to field with established spray intervals than were low users or nonusers.

Overall, the National Evaluation of Extension's Integrated Pest Management Programs served several useful purposes. It provided a background profile of high, low, and nonusers, a better understanding of why they used IPM, an evaluation on the effectiveness of extension delivery methods, and an economic evaluation of IPM based on high, low, and nonuse of IPM methods. These results show the positive aspects of grower acceptance and implementation of IPM practices and the important role that the extension specialists and county extension agents play in the delivery of IPM information. It also highlighted current and future needs in the implementation of IPM at the grower level. Less effective delivery methods were determined and can be revised or replaced to provide more effective dissemination of IPM information. In addition, private IPM consultants were also identified as prominent users of extension information on IPM and probably represent another clientele group that should be considered in the delivery of IPM information.

Future Direction for IPM

Several important management strategies have been developed or are in the process of development that will have major impact on IPM as it is currently used. These new strategies include the use of predictive models, genetically engineered plants and control organisms, altered pest communities for social insects, and manipulation of parasitoids and predators with kairomones to increase their effectiveness.

Several models for groundnuts have been developed and are in various stages of use and/or verification. Foremost among these is the PNUTGRO, a groundnut crop growth simulation model developed by Boote et al. (1987). This model is a process-oriented growth and yield model that predicts groundnut development based on cultivar, sowing date, row and plant spacings, and irrigation. Version V1.0 was designed as a research tool and allows input of data for different management variables, with the exception of pest variables. Mack et al. (1987) developed a mathematical model to describe the population dynamics of the LCB, and more recently developed a management system model for the LCB that can be used by growers to predict the potential for an infestation and damage by the LCB (Mack et al., in press). Components for different models need to be combined to integrate growth and yield variables, such as variety, sowing date, soil type, etc., with management variables, such as insect, disease, and weed pests, irrigation, etc., and economic variables, such as pesticide and application costs, crop value, predicted yield, etc. Dynamic predictive models would assist growers and/or consultants in making the best management decision based on the integration of all pertinent variables.

Host plant resistance still offers one of the least expensive methods for managing pest insects and is probably one of the most applicable strategies for farmers in developing nations. Germplasm with *A. craccivora*/rosette, termite, thrips/TSWV, and leafhopper resistance has been identified and in some instances is being used. Aflatoxin contamination of groundnut is also one of the most pressing problems for farmers in developing countries and is also associated with insect damage to pods (McDonald and Harkness 1963, 1964; Lynch and Wilson 1991). Research is currently underway to identify and/or develop germplasm with resistance to aflatoxin formation. This germplasm needs to be evaluated under intensive soil-insect pressure for aflatoxin formation, and resistant germplasm needs to be combined with germplasm with resistance to other pests, both insects and diseases, to produce multiple pest resistant groundnut lines.

Genetic engineering of plants and other organisms by introduction of simply inherited traits is now a reality. These procedures offer tremendous potential for greatly reducing the time required to develop needed traits in germplasm; the gene(s) may be transferred directly to adapted, high-yielding lines with acceptable agronomic traits rather than being developed through conventional breeding procedures. A prime example is the insertion of the gene for delta endotoxin of *Bacillus thuringiensis* into tomato (*Lycopersicon esculentum*), cotton (*Gossypium hirsutum*), and tobacco (*Nicotiana tabacum*). The delta endotoxin is then produced by the plant tissue and is toxic to lepidopterous larvae ingesting host foliage. Researchers at several universities in the USA are attempting to insert this gene into groundnut. Resistance to a number of pests also has been identified in wild species of *Arachis* (see Lynch 1990 for a review) by scientists at ICRISAT and U.S. universities, and both conventional and genetic engineering methods are being used/developed to transfer resistance from wild species to *A. hypogaea*.

Social insects such as termites and ants are among the most important insect pests of groundnut in developing nations. As noted by Wightman et al. (1990), additional research is needed to develop methods whereby slow-release toxic baits are picked up by foraging insects, carried back to the colony, and transferred to other members of the colony. The toxin may act directly on the insects or, in the case of termites that produce fungal gardens, on the fungi. Cooperative research with ICRISAT and the Natural Resources Institute, UK, is currently in progress to develop such inexpensive and long-lasting methods.

New and improved methods to manage parasitoids and predators is another area with potential for improved pest management in the developed countries (Gross 1981). Allelochemicals, particularly kairomones, directly influence host location, selection, and acceptance by parasitoids. These chemicals may be used to attract feral entomophages to a particular area or to retain released parasitoids in the target area. In the developed nations, inundative releases of laboratory-produced entomophages are also likely to become viable IPM control strategies available to producers.

IPM practices have advanced considerably over the past 10 years. Insecticides at one time were the sole medium considered for control of both economic and subeconomic populations of insects. Insecticides are still a major component in the integrated approach to the management of insects. Adoption of IPM methods such as scouting, establishment of ETs, consideration for the prevalence of parasitoids, predators, and insect pathogens, use of resistant plant varieties, adoption of cultural practices to circumvent major pest damage, and selection of pesticides based on reduced effect on beneficial insects and environmental hazard are now a reality in many IPM programs.

References

Amin, P.W. 1985a. Methodology of screening against ests of groundnut. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics. 22 pp. (Limited distribution.)

Amin, P.W. 1985b. Apparent resistance of groundnut cultivar Robut 33-1 to bud necrosis disease. Plant Disease 69:718-719.

Amin, P.W., and **Mohammad, A.B.** 1980. Groundnut pest research at ICRISAT. Pages 158-166 *in* Proceedings of the International Workshop on Groundnuts, 13–17 Oct 1980, ICRISAT Center, India. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Amin, P.W., Singh, K.N., Dwivedi, S.L., and **Rao, V.R.** 1985. Sources of resistance to jassid (*Empoasca kerri* Pruthi), thrips (*Frankliniella schultzei* Trybom), and termites (*Odontotermes* sp.) in groundnut (*Arachis hypogaea* L.). Peanut Science 12:58-60.

Bass, M.H., and **Arant, F.S.** 1973. Insect pests. Pages 383-428 *in* Peanuts – culture and use. Stillwater, Oklahoma, USA: American Peanut Research and Education Association.

Batra, S.W.T. 1982. Biological control in agroecosystems. Science 215:134-139.

Bockelee-Morvan, A. 1983. The different varieties of groundnut: geographical and climatic distribution, availability. Les differentes varietes d'arachide: repartition geographique et climatique disponibilite. (In Fr, En.) Oleagineux 38:73-76.

Boote, K.J., Jones, J.W., Hoogenboom, G., Wilkerson, G.G., and **Jagtap, S.S.** 1987. PNUTGRO V1.0, peanut crop growth simulation model, user's guide. Gainesville, Florida, USA: Florida Agricultural Experiment Station. 46 pp.

Boyer, W.P., Warren, L.O., and **Lincoln, C.** 1962. Cotton insect scouting in Arkansas. Bulletin, Arkansas Agricultural Experiment Station no. 656. 40 pp.

Brar, K.S., and **Sandhu, G.S.** 1980. Bionomics and control of white grubs in India. Oilseeds Journal 10:44-55.

Campbell, W.V., and **Wynne, J.C.** 1980. Resistance of groundnuts to insects and mites. Pages 149-157 *in* Proceedings of the International Workshop on Groundnuts, 13–17 Oct 1980, ICRISAT Center, India. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Campbell, W.V., and **Wynne, J.C.** 1985. Influence of the insect-resistant peanut cultivar NC 6 on performance of soil insecticides. Journal of Economic Entomology 78:113-116.

Campbell, W.V., Emery, D.A., and **Gregory, W.C.** 1971. Registration of GP-NC 343 peanut germplasm. Crop Science 11:605.

Campbell, W.V., Emery, D.A., and **Wynne, J.C.** 1975. Registration of four germplasm lines of peanut (Reg. Nos. GP5 to GP8). Crop Science 15:738-739.

Campbell, W.V., Emery, D.A., and **Wynne, J.C.** 1976. Resistance of peanuts to the potato leafhopper. Peanut Science 3:40-43.

Campbell, W.V., Wynne, J.C., Emery, D.A., and **Mozingo, R.W.** 1977. Registration of NC 6 peanuts. Crop Science 17:346.

Carolla, H.L. 1984. Edaphic studies on the population biology of the lesser cornstalk borer (*Elasmopalpus lignosellus* [Zeller]). Ph.D. thesis, Texas A&M University, College Station, Texas, USA.

Culbreath, A.K., Todd, J.W., and **Demski, J.W.** 1990. Epidemiology of TSWV on peanut. Proceedings of American Peanut Research and Education Society 22:81.

Culbreath, A.K., Todd, J.W., and **Demski, J.W.** 1992. Disease progress of tomato spotted wilt virus in Florunner and Southern Runner peanut cultivars. Phytopathology 82:766-771.

Davies, J.C. 1972. Studies on the ecology of *Aphis craccivora* Koch (Hemiptera: Aphididae), the vector of rosette disease of groundnut in Uganda. Bulletin of Entomological Research 62:169-181.

Douce, G.K. 1982. 1981 Georgia integrated pest management program facts. Athens, Georgia, USA: University of Georgia, Georgia Cooperative Extension Service. 66 pp.

Douce, G.K., Linder, K., Wetzstein, M.E., and **Musser, W.N.** 1983. Evaluating extension integrated pest management programs with factor analysis indices. Bulletin of the Entomological Society of America 29:43-46.

Farrell, J.A.K. 1976a. Effects of groundnut sowing date and plant spacing on rosette virus disease in Malawi. Bulletin of Entomological Research 66:159-171.

Farrell, J.A.K. 1976b. Effects of groundnut crop density on the population dynamics of *Aphis craccivora* Koch (Hemiptera: Aphididae) in Malawi. Bulletin of Entomological Research 66:317-329.

Feakin, S.D. (ed.) 1973. Pest control in groundnuts. 3rd edn. PANS Manual no. 2. London, UK: Center for Overseas Pest Research.

Gibbons, R.W. 1977. Groundnut rosette virus. Pages 19-21 *in* Diseases, pests and weeds in tropical crops (Kranz, J., Schmutterer, J., and Koch, W., eds.). Berlin, Federal Republic of Germany: Verlag Paul Parey.

Gibbons, R.W., and **Mercer, P.C.** 1972. Peanut disease control in Malawi, Central Africa. Journal of American Peanut Research Education Association 4:58-66.

Gross, H.R., Jr. 1981. Employment of kairomones in the management of parasitoids. Pages 137-150 *in* Semiochemicals: their role in pest control (Nordlund, D.A., ed.). New York, USA: John Wiley.

Hatfield, J.L., and Thomason, I.J. (eds.) 1982. Biometeorology in integrated pest management: proceedings of a Conference on Biometeorology and Integrated Pest Management, University of California, Davis, California. New York, USA: Academic Press. 491 pp.

Hull, R. 1964. Spread of groundnut rosette virus by *Aphis craccivora* (Koch). Nature 202:213-214.

Johnson, R.A., and **Gumel, M.H.** 1981. Termite damage and crop loss studies in Nigeria – the incidence of termite scarified groundnut pods and resulting kernel contamination in field and market samples. Tropical Pest Management 27:343-350.

Johnson, S.J. 1978. The population dynamics and natural mortality of the lesser cornstalk borer, *Elasmopalpus lignosellus*, in the peanut agroecosystem and the biology of selected primary parasites. Ph.D. thesis, Texas A&M University, College Station, Texas, USA.

Kousalya, G., Ayyavoo, R., Krishnamurthy, C.S., Kandaswamy, T. K., and **Bhaskaran, S.** 1971. Effect of spacing, roguing and weeding on the incidence of rosette disease of groundnut with observations on the aphid vector, *Aphis craccivora* Koch. Madras Agricultural Journal 58:495-505.

Leuck, D.B. 1966. Biology of the lesser cornstalk borer in South Georgia. Journal of Economic Entomology 59:597-801.

Leuck, D.B. 1967. Lesser cornstalk borer damage to peanut plants. Journal of Economic Entomology 60:1549-1551.

Lincoln, C., Boyer, W.P., Dowell, G.C., Barnes, G., and **Dean, G.** 1970. Six years' experience with point sample cotton insect scouting. Bulletin, Arkansas Agriculture Experiment Station no. 754. 39 pp.

Lynch, R.E. 1984. Damage and preference of lesser cornstalk borer (Lepidoptera: Pyralidae) larvae for peanut pods in different stages of maturity. Journal of Economic Entomology 77:360-363.

Lynch, R.E. 1990. Resistance in peanut to major arthropod pests. Florida Entomologist 73:422-445.

Lynch, R.E., and **Wilson, D.M.** 1991. Enhanced infection of peanut, *Arachis hypogaea* L., seeds with *Aspergillus flavus* group fungi due to external scarification of peanut pods by the lesser cornstalk borer, *Elasmopalpus lignosellus* (Zeller). Peanut Science 18:110-116.

Lynch, R.E., Ouedraogo, A.P., and **Dicko, I.** 1986. Insect damage to groundnut in semi-arid tropical Africa. Pages 175-183 *in* Agrometeorology of groundnut: proceedings of an International Symposium, 21–26 Aug 1985, ICRISAT Sahelian Center, Niamey, Niger. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Lynch, R.E., Ouedraogo, A.P., and **Some, S.A.** 1990. Effect of harvest date and termite-resistant varieties on termite and millipede damage to groundnut in Burkina Faso. Pages 87-89 *in* Summary proceedings of the First ICRISAT Regional Groundnut Meeting for West Africa, 13–16 Sep 1988, ICRISAT Sahelian Center, Niamey, Niger. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Mack, T.P., and **Appel, A.G.** 1986. Water relations of immature and adult lesser cornstalk borers, *Elasmopalpus lignosellus* (Zeller) (Lepidoptera: Pyralidae). Annals of the Entomological Society of America 79:579-582.

Mack, T.P., Appel, A.G., Backman, C.B., and **Trichilo, P.J.** 1988. Water relations of several arthropod predators in the peanut agroecosystem. Environmental Entomology 17:778-781.

Mack, T.P., Davis, D.P., and **Lynch, R.E.** (In press.) Development and validation of a management system for the lesser cornstalk borer (Lepidoptera: Pyralidae) attacking peanut fields in the southeastern U.S. Journal of Economic Entomology.

Mack, T.P., Smith, J.W., Jr., and **Reed, R.B.** 1987. A mathematical model of the population dynamics of the lesser cornstalk borer, *Elasmopalpus lignosellus*. Ecological Modelling 39:269-286.

McDonald, D., and **Harkness, C.** 1963. Growth of *Aspergillus flavus* and production of aflatoxin in groundnuts. Part 2. Tropical Science 5:143-154.

McDonald, D., and **Harkness, C.** 1964. Growth of *Aspergillus flavus* and production of aflatoxin in groundnuts. Part 4. Tropical Science 6:12-27.

Metcalf, R.L., and **Luckman, W.H.** 1975. Introduction to insect pest management. New York, USA: Wiley. 587 pp.

Musser, W.N., Wetzstein, M.E., Reece, S.Y., Varca, P.E., Edwards, P.E., and **Douce, G.K.** 1986. Beliefs of farmers and adoption of integrated pest management. Agricultural Economics Research 38:34-44.

NAS (National Academy of Sciences). 1969. Insect pest management and control. Publication no. 1695. Washington, D.C., USA: NAS. 508 pp.

Nigam, S.N. 1987. A review of the present status of the genetic resources of the ICRISAT Regional Groundnut Program of southern Africa cooperative regional yield trials, and of rosette virus resistance breeding. Pages 15-30 *in* Proceedings of the Second Regional Groundnut Workshop for Southern Africa, 10–14 Feb 1986, Harare, Zimbabwe. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Nigam, S.N., Dwivedi, S.L., and **Gibbons, R.W.** 1991. Groundnut breeding: constraints, achievements and future possibilities. Plant Breeding Abstracts 61:1127-1136.

Rajotte, E.G., Kazmierczak, R.F., Norton, G.W., Lambur, M.T., and **Allen, W.A.** 1987. The national evaluation of extension's integrated pest management (IPM) programs. Appendix 8. Georgia peanut IPM impact study. Publication no. 491-019. Blacksburg, Virginia, USA: Virginia Polytechnic Institute and State University. 73 pp.

Sears, D.E., and **Smith, J.W., Jr.** 1975. A natural mortality table for the corn earworm on peanuts. Progress Report, Texas Agricultural Experiment Station no. 3344C. 7 pp.

Smith, J.W., and **Barfield, C.S.** 1982. Management of preharvest insects. Pages 250-325 *in* Peanut science and technology (Pattee, H.E., and Young, C.T., eds.). Yoakum, Texas, USA: American Peanut Research and Education Society.

Smith, J.W., Jr., Johnson, S.J., and **Sams, R.L.** 1981. Spatial distribution of lesser cornstalk borer eggs in peanuts. Environmental Entomology 10:192-193.

Stern, V.M., Smith, R.F., van den Bosch, R., and **Hagen, K.S.** 1959. The integrated control concept. Hilgardia 29:81-101.

Wightman, J.A., and **Amin, P.W.** 1988. Groundnut pests and their control in the semi-arid tropics. Tropical Pest Management 34:218-226.

Wightman, J.A., Amin, P.W., Rao, G.V.R., and **Dick, K.M.** 1987. Research on groundnut pests at ICRISAT. Pages 103-114 *in* Proceedings of the Second Regional Groundnut Workshop for Southern Africa, 10–14 Feb 1986, Harare, Zimbabwe. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Wightman, J.A., Dick, K.M., Rao, G.V.R., Shanower, T.G., and **Gold, C.G.** 1990. Pests of groundnut in the semi-arid tropics. Pages 243-322 *in* Insect pests of tropical food legumes (Singh, S. R., ed.). New York, USA: John Wiley.

Wiseman, B.R., and **Davis, F.M.** 1990. Plant resistance to insects attacking corn and grain sorghum. Florida Entomologist 73:446-458.

Discussion

P.W. Amin: Of the three categories of IPM, high, low, and nonusers, why are 'nonusers' nonusers?
R.E. Lynch: The three categories are based on acceptance of IPM procedures. A certain segment of the farmers, not amicable to the educational program provided by extension, choose not to follow IPM recommendations.

P.W. Amin: Can you indicate strategies for IPM for subsistence farmers who have low literacy and face remoteness from universities, frequent absence of village-level workers, and multiple pests and diseases in the tropics?
R.E. Lynch: In IPM for subsistence farmers, education is the key. This is not to say education in the academic sense, but education through local extension workers and demonstration plots to gain practical knowledge. Through local and readily available personnel and demonstration of IMP, subsistence farmers learn the value of IPM.

P.W. Amin: What is the time schedule for developing an 'effective' IPM program?
R.E. Lynch: There is no effective 'time scale' for the development of IPM. Various components are applicable after determination of their usefulness by research. The various components can then be implemented.

M.V. Potdar: Is there a close relationship between climatic parameters and insect pest outbreaks, and is it possible to use these relationships in forecasting some groundnut pests?
R.E. Lynch: Yes, in several cases climatic data can be used to predict pest outbreaks. Examples include the prediction of migratory locust outbreaks in Africa and the warning systems that have been developed.

P. Subrahmanyam: What is the proportion of resources allocation to different components of IPM in Burkina Faso?
R.E. Lynch: When we consider various components of IPM, one has to consider different pests separately. For example, some insects can be controlled effectively by biocontrol agents while others by cultural practices, chemicals or host-plant resistance. The first thing one needs to work out is the economic impact of various insect pests in a particular area. For example, termites are considered to be important in Burkina Faso while millipedes are important in Senegal. Based on these considerations one can work out the resource allocation to various components.

D.S. Bisht: Scouting and surveillance are important events in taking pest management decisions. Are there any efficient tools to make the surveillance more effective?
R.E. Lynch: Pheromone traps are one such tool useful for monitoring and also to predict insect populations. There are some insect forecasting systems that can predict insect migrations.

D.S. Bisht: Are there any safer insecticides which can provide good insect control?
R.E. Lynch: Yes, new generation insecticides are much safer than old chemicals like DDT, lindane, or chlordane.

H. Bingchao: Is it necessary to set a common IPM plan in groundnut on a global scale?
R.E. Lynch: IPM practices in general have application over many areas. For example, each region of the world, i.e., Asia, Africa, and America, has their component of defoliating lepidopterous insects such as *Helicoverpa* sp and *Spodoptera* sp. Results from research on these insects may be extended to different regions. Conversely, pest species such as millipedes in West Africa, white grubs in Asia, and wireworms in USA must be studied separately.

H. Bingchao: How to set the economic thresholds for applying insecticides?
R.E. Lynch: Generally, two major methods have been used to establish economic thresholds. Firstly, the use of insecticides to control insect pest population where they are sufficient to provide a gradient of insect damage, and, secondly, to artificially infest with known populations of insects during specific growth stages. Screen cages can be used for short periods of time to exclude damage by other insects.

H. Bingchao: How to set economic thresholds when more than two kinds of pests/diseases occur at the same time?

R.E. Lynch: Establishment of economic thresholds for more than one or two species of insects, or interaction with insects or plant pathogens and weeds is more difficult. Simulation models to predict yield loss under these situations followed by field evaluations to validate the simulation will be useful to determine losses due to multiple pest damage.

S.S. Bhadauria: Are there any efforts made to educate consumers about the difference in quality of groundnut products produced under heavy insecticides and low/no insecticides? Do we have data on the residual effects of insecticides? Educating consumers on the better quality of groundnut produced following IPM and their willingness to pay more for such products will act as an incentive to farmers to follow IPM.

R.E. Lynch: You are talking about a very small segment of population that is willing to pay higher prices for organically grown food. Nonetheless your point is well taken. A well-educated consumer is just as important as a well-educated producer.

Utilizing *Arachis* Germplasm Resources

H.T. Stalker[1]

Abstract

The genus Arachis *contains 70 or more diploid and tetraploid species. The number of accessions available for biosystematic study and utilization has increased from approximately 120 during the mid-1970s to more than 825 in the 1990s. Continued efforts are still needed to collect a representative sample of the variations in the genus. Maintenance of the germplasm is both difficult and labor intensive, and efforts to duplicate accessions at different institutions are of high priority.* Arachis *species have been divided into seven sections and the 20 to 25 species in section* Arachis *are cross compatible with the cultivated species* A. hypogaea. *Limited success has been achieved in making intersectional hybrids with* A. hypogaea *during recent years. Hybridization barriers are usually postzygotic events, and several in-vitro and in-vivo techniques are useful for increasing the frequency of embryo growth. Approximately 20% of the* Arachis *accessions have been evaluated at least once for host plant resistance or quality characters, and high levels of resistance to many diseases, viruses, and insect and nematode pests have been identified. Most important for crop improvement will be species in section* Arachis. *Three cytological routes (triploid-hexaploid-tetraploid, autotetraploids, and amphidiploids) have been used in attempts to introgress genes from diploid species to* A. hypogaea. *At least one* A. hypogaea × A. cardenasii *population has been developed with resistance to many pests and with high yield potentials. Utilization of the wild* Arachis *species required a long-term investment and the species are beginning to fulfill their potential for genetic improvement of* A. hypogaea.

Résumé

***Utilisation des ressources génétiques d'*Arachis:** *Le genre* Arachis *contient au moins 70 espèces diploïdes et tétraploïdes. Le nombre d'obtentions disponibles pour une étude biosystématique et l'utilisation a augmenté de 120 environ pendant la moitié des années 1970 jusqu'à plus de 825 au cours des années 1990. Des efforts constants demeurent nécessaires pour collecter un échantillon représentatif des variations du genre. L'entretien des ressources génétiques est difficile car il exige beaucoup de main d'oeuvre et une priorité très élevée doit être accordée aux efforts pour produire en double les obtentions dans différentes institutions. Les espèces d'*Arachis *ont été classées en sept sections et les 20 à 25 espèces dans la section* Arachis *sont compatibles avec les espèces cultivées d'* A. hypogaea. *Un succès restreint a été obtenu depuis quelques années dans la préparation d'hybrides inter-sectionnels avec* A. hypogaea. *Les barrières contre l'hybridation sont généralement d'ordre post-zygotique et plusieurs techniques in-vitro et in-vivo sont utiles pour accroître la fréquence de la croissance embryonnaire. Environ 20% des obtentions d'*Arachis *on été évaluées une fois pour la résistance du plant hôte ou des caractéristiques de qualité; un niveau élevé de résistance à bien des maladies, virus, insectes et nématodes a été identifié. Les plus importantes pour l'amélioration des cultures sont les espèces de la section* Arachis. *Trois voies cytologiques (Triploïde-hexaploïde-tétraploïed), autotetraploïde et amphidiploïde) ont été utilisées pour essayer d'incorporer des gènes d'espèces diploïdes dans* A. hypogaea. *Au moins un peuplement* A. hypogaea × A. cardenasii *a été mis au point avec de la résistance contre bien des ennemis et un potentiel de rendement très élevé. L'utilisation des espèces sauvages d'*Arachis *a exigé un investissement à long terme et les espèces commencent à remplir leur potentiel d'amélioration génétique d'* A. hypogaea.

1. Professor of Crop Science, Department of Crop Science, North Carolina State University, P.O. Box 7629, Raleigh, NC 27695-7629, USA.

This paper was made possible through support provided by the Office of Agriculture, Bureau of Research and Development, U.S. Agency for International Development, under Grant No. DAN 4048-G-00-0041-00.

Stalker, H.T. 1992. Utilizing *Arachis* germplasm resources. Pages 281–295 *in* Groundnut – a global perspective: proceedings of an international workshop, 25–29 Nov 1991, ICRISAT Center, India (Nigam, S.N., ed.). Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

The genus *Arachis* is large and widely distributed in South America. Species are found in an array of habitats ranging from arid to semiaquatic. While most species are diploid (2n = 2x = 20), polyploidy has arisen independently at least twice during the evolution of the genus. Five species have been cultivated, including *A. villosulicarpa* Hoehne by peoples in the northwestern area of Mato Grosso, Brazil (Gregory et al. 1973); *A. repens* Handro primarily as a ground cover in many regions of South America; *A. glabrata* Benth. and *A. pintoi* Krap. et Greg. *nom. nud.* as forages in South America, Australia, and the USA; and *A. hypogaea* L. in many tropical to subtropical regions. Of these, only *A. hypogaea* has been domesticated and grown extensively for seeds and oil. Although efforts to utilize the germplasm resources in the genus have included forage use of wild species (Prine et al. 1986, 1990; Cameron et al. 1989), most utilization efforts have been to introgress traits to *A. hypogaea*. This review will be restricted to using *Arachis* germplasm resources for improvement of the cultivated groundnut (*Arachis hypogaea*).

Several reviews during the past 10 years have summarized much of the information needed to initiate an interspecific hybrid breeding program in *Arachis* (Smartt and Stalker 1982; Moss 1985; Stalker 1985; Singh and Gibbons 1986; Stalker and Moss 1987; Moss et al. 1989; Singh et al. 1991a). In this chapter, a review of the botanical and genetical structure of the genus will be made to better understand the potential value of *Arachis* species. This paper will review germplasm resources, maintenance of accessions, traits of agronomic importance, biosystematic relationships, and their bearing on the potential for introgressing desirable characters to the cultivated groundnut. Finally, areas for future investigation will be presented.

Germplasm Distributions and Collections

Arachis species are found in a large area of South America from the Atlantic Ocean to the foothills of the Andes Mountains and from the mouth of the Amazon River in the north to approximately 34° S in Uruguay. The greatest number of species are found in western central Brazil, followed by regions of Bolivia (Valls et al. 1985). Taxa of *Arachis* have been collected since the early 1800s, but not until the late 1950s were systematic efforts made to acquire the species variation in the genus. Since 1958, more than 25 plant exploration trips have been conducted to collect *Arachis* species. Most of these efforts were due to the designation of groundnut as a priority crop by the International Board for Plant Genetic Resources (IBPGR). During the late 1970s, approximately 120 accessions were maintained in germplasm collections in the USA. The number has risen significantly during recent years, and many species are now represented by more than one accession. However, an enormous effort will be required to complete field collecting to fully sample the variation in the genus.

Simpson (1982) estimated that only 55 to 65% of the species have been collected; and several areas in Brazil, Argentina, Bolivia, and Paraguay have been designated for future collection efforts (Fig. 1). The highest priority areas are the Mato Grosso and Mato Grosso do Sul States of Brazil and much of Paraguay (Valls et al. 1985). Immediate effort is required in areas where *Arachis* species have not been previously collected; where *Arachis* species have been previously reported, but no living specimens are available; areas in which species have been previously found, but variation patterns warrant additional collection

Figure 1. Areas of South America from which collection of *Arachis* species is most urgently needed. (Source: Composited from Simpson 1990 figures).

(for example, in northern Argentina); and, most importantly, where *Arachis* is expected to be found, but civilization is encroaching on native habitats (Simpson 1990). An extended period of time over many collection trips will be needed to complete the task to overcome obstacles of poor transportation and adverse weather conditions.

During the past 2 years surveys were made of 1) *Arachis* germplasm accession numbers reported in the literature and 2) curators who are maintaining living plants or seeds of groundnut species. According to the information published in the USDA Plant Introduction (PI) records, Gregory et al. (1973), Simpson and Higgins (1984), and other records acquired from collectors during the past few years, about 1386 wild *Arachis* accessions have been collected in South America. Some of these are probably herbarium specimens only, so the actual number of potentially living accessions is somewhat less. IBPGR designated the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) as an international depository for *Arachis* germplasm and the Centro Nacional de Recursos Geneticos (CENARGEN) received IBPGR funding to maintain a living collection – especially of accessions that are difficult to maintain outside their native habitat.

At present, the status of the *Arachis* germplasm collections is more satisfactory than at any time in the past. Efforts are being made at several institutions to improve preservation of living plants and to increase seed stocks. Many of the early collections have been lost, but preservation of recently acquired accessions has been more successful. Of the 1386 collector's numbers, PIs, or other references to collections found in the literature, about 550 are currently being maintained in the USA and perhaps as many as 276 additional unique accessions are being maintained in Brazil. These and subsequent numbers exclude mutants and sequentially numbered plants of original collections. Unfortunately, records have not always been kept in a systematic fashion, and some confusion exists as to what should be available for study. For example, after plant materials are introduced to the USA, a list of accessions should be submitted to the U.S. Department of Agriculture (USDA) requesting the assignment of PI numbers for the accessions. However, stated procedures are not enforced and at least 166 accessions are currently maintained in the USA and identified only by the collectors' number because they have not been assigned PIs. This number not only includes the many recent introductions for which numbers will be obtained, but also a large number of accessions introduced 15 to 20 years ago. In addition, many of the 811 PIs assigned for *Arachis* species were given to materials introduced multiple times, and only 722 PIs represent unique accessions. The USDA curator currently maintains 223 wild *Arachis* accessions. In addition, 255 accessions are maintained at North Carolina State University, 490 at Texas A&M University, and 207 at ICRISAT. While most accessions are duplicated at two or more of the above locations, none of the institutions maintains all of the wild species accessions. An aggressive effort is needed to identify and duplicate entries that are being maintained at only one institution.

Many *Arachis* accessions have been lost because of improper storage, poor seed viability following introduction, short storage viability even in good facilities, naturally weak plant specimens, or unsuitable growing conditions under cultivation. Moreover, germplasm maintenance of the *Arachis* species is difficult because a large number of accessions produce few or no seeds in greenhouses or seed nurseries – e.g., many species of sections *Ambinervosae*, *Erectoides*, and *Extranervosae*. Further, seeds of several section *Erectoides* species will become inviable if they are dried to normal storage moisture conditions. Many species of the genus produce so few seeds that plants must be vegetatively propagated in the greenhouse. This is especially true for section *Rhizomatosae* and several perennial section *Arachis* taxa. Not only is seed production and maintenance difficult, but also labor intensive and expensive. Because of the spreading growth habit of most *Arachis* species, a large land area is required for seed production to avoid seed contamination cross-pollination. Either specialized equipment or a large labor force is required to adequately increase the number of seeds that are recovered mostly by sifting soil. Another problem has been the lack of knowledge about plant-to-plant variability within accessions, and 'off-type' plants have often been rogued in nurseries to preserve seed purity.

Optimal methods to maintain and regenerate *Arachis* species are yet to be established. Many species do not initiate pegging in the greenhouse but, when they are sown in the field, a larger number will complete the sexual life cycle. Other species flower profusely under long-day conditions, but produce a higher percentage of pegs per total number of flowers under short days (Stalker and Wynne 1983). On the other hand, *A. chacoense* Krap. et Greg. *nom. nud.*, *A. villosa* Benth., *A. correntina* (Burk.) Krap. et Greg. *nom. nud.*, and other taxa will not flower under short-day conditions. Plant-to-plant variation within an *A. cardenasii* Krap. et Greg. *nom. nud.* accession has also been observed for number of seeds under greenhouse conditions (H.T. Stalker, unpublished data 1991); thus, much of the seed recovered in field nurseries may be from a limited number of plants and not be representative of the accessions as a whole. To guarantee viable seed, several curators establish seed nurseries annually, whereas a longer regeneration period is more desirable to preserve plants containing rare genes found in original field populations. Several of the above-mentioned practices can lead to genetic drift and significantly narrow the germplasm base of accessions within a species.

Species Diversity and Biosystematics

The first *Arachis* species described was *A. hypogaea* by Linneaus in 1753. Five wild diploid species were described nearly a century later. Since then, a total of 23 species (Table 1) and one interspecific hybrid have been validly named. In addition, at least 13 names have been used in the literature for other taxa. Although the exact number of species in the genus is unknown, estimates of 70 or more are common (Valls et al. 1985; Stalker and Moss 1987; Krapovickas 1990). The last monograph published was by F.J. Her-

Table 1. Taxonomic summary of genus *Arachis* (after Gregory et al. 1973; Krapovickas 1990).

Section[1]	Series[1]	No. species	Validly named species
Arachis	*Annuae*	12	*A. batizocoi* Krap. et Greg. *A. glandulifera* Stalker
	Perennes	20	*A. diogoi* Hoehne *A. helodes* Martius ex Krap. et Rig. *A. villosa* Benth. var *villosa* *A. villosa* var *correntina* Burk.
	Amphiploides	2	*A. hypogaea* L. *A. monticola* Krap. et Rig.
Ambinervosae		4	*A. pusilla* Benth.
Caulorhizae		2	*A. repens* Handro
Erectoides	*Trifoliolatae*	2	*A. guaranitica* Chod. et Hassl. *A. tuberosa* Benth.
	Tetrafoliolatae	15	*A. benthamii* Handro *A. martii* Handro *A. paraguariensis* Chod. et Hassl.
	Procumbensae	8	*A. rigonii* Krap. et Greg.
Extranervosae		8	*A. lutescens* Krap. et Rig. *A. marginata* Gard. *A. prostrata* Benth. *A. villosulicarpa* Hoehne
Rhizomatosae	*Prorhizomatosae*	1	*A. burkartii* Handro
	Eurhizomatosae	2	*A. glabrata* Benth. *A. hagenbeckii* Harms
Triseminalae		1	
Uncertain affinity			*A. angustifolia* (Chod. et Hassl.) Killip
Total		77	

1. All sections and series reported herein are taxonomically written with Krap. et Greg. nom. nud. except section *Arachis* nom. nud.

mann in 1954. After conducting a numerical taxonomic study for the group of species most closely related to *A. hypogaea*, Stalker (1990) concluded that between 20 and 25 species exist in the group. Only one species has been described from the large number of collections made since 1976 (Stalker 1991), and a taxonomic revision of the genus is one of the highest priorities for proper documentation of *Arachis* germplasm.

Based on cross-compatibility and morphological relationships, *Arachis* species have been grouped into seven sections by Krapovickas (1969, 1973), Gregory et al. (1973), and eight sections by Krapovickas (1990). Although none of the above sectional names have been validly described, the divisions are convenient for studying groups of *Arachis* species. Because all of the sectional classifications are different, and the scheme proposed by Gregory et al. (1973) is the most widely cited, it is the one used in the remainder of this paper (Table 1).

Interspecific hybridization is possible among most species within a section, whereas hybrids between species of different sections are difficult to produce (Gregory and Gregory 1979). Further, intrasectional hybrids range from completely sterile to highly fertile, whereas intersectional hybrids are always sterile. Genomic groups have been proposed by Smartt and Stalker (1982) and Stalker (1991) as follows: A, B, and D in section *Arachis*; Am in *Ambinervosae*; C in *Caulorhizae*, E in *Erectoides* (subgenomes E_1, E_2, E_3 corresponding to series); Ex in *Extranervosae*; R_1 in *Prorhizomatosae* and T in *Triseminales*. Much of the cytological and genetical work needed for confirmation of genomes of *Arachis* remains to be completed, but the broad outline serves as a useful model for attempts to utilize the genetic resources of the genus.

Cytological analyses in *Arachis* have recently been summarized elsewhere (Stalker 1985; Stalker and Moss 1987; Singh et al. 1991a); thus, only a short review will be presented in this paper. *Arachis hypogaea* is an allotetraploid species. Six A-genome species (*A. cardenasii*, *A. chacoense*, *A. correntina*, A. *duranensis nom. nud.*, *A. villosa*, and *A. ipaensis nom. nud.*) and one B-genome species (*A. batizocoi*) have been hypothesized as possible progenitors of *A. hypogaea* (for review, see Stalker and Moss 1987; Murty and Jahnavi 1986; Kochert et al. 1991). In theory, gene introgression to *A. hypogaea* should be more efficient when progenitor species are used as parents in crossing programs and, thus, studying the evolution of the cultivated groundnut could have practical applications. Although *A. hypogaea* has been proposed to have components of the A and B genomes, several recent studies, including DNA restriction fragment length polymorphisms (RFLPs) (Kochert et al. 1991), DNA polymerase chain reactions (PCRs) (Halward et al. 1991a), isozymes (H.T. Stalker, unpublished data 1990), and seed storage proteins (C.M. Bianchi-Hall, R.D. Keys, and H.T. Stalker, unpublished data, 1990), have indicated that *A. batizocoi* (B genome) is not in the parentage of the cultivated species. A similar observation came from chloroplast DNA analyses that indicated that *A. batizocoi* cannot be the female parent of *A. hypogaea* whereas *A. duranensis* had the same banding profiles as the cultivated groundnut and *A. monticola* (K. Hilu and H. T. Stalker, unpublished data, 1990). However, hybrids between *A. hypogaea* and amphidiploids involving both A and B-genome species are more fertile than when only A-genome species are utilized (Singh 1986a). The conclusions drawn from the above molecular studies are that 1) *A. hypogaea* had an allopolyploid origin, 2) a large amount of genomic differentiation between the diploid A and B genomes has occurred as was previously indicated from differential karyotypes (Stalker and Dalmacio 1981; Singh and Moss 1982) or the low fertility levels in A-B genome F_1 hybrids (for review, see Stalker and Moss 1987; Stalker et al. 1991a), and 3) definitive identification of the progenitors of *A. hypogaea* has not been completed, although *A. duranensis* is a likely candidate for the female parent. Additionally, the evidence suggests that none of the currently known *A. batizocoi* accessions were involved in the ancestry of *A. hypogaea*. The best evidence implying *A. batizocoi* as a progenitor species came from cytological data indicating that this species could have contributed one of the two smallest chromosomes (number 19 or 20) in the *A. hypogaea* genome; however, with the high frequency of translocations observed among *A. batizocoi* accessions (Stalker et al. 1991b) and implied from the large number (5) of chromosomes with satellites in different cultivars (Stalker and Dalmacio 1986), a mechanism for sufficient karyotypic differentiation of a second A-genome species can easily be visualized to account for the differences in chromosome morphology in *A. hypogaea*.

Biochemical and molecular data have also been used to estimate genetic variation and species relationships in the genus. A large amount of differentiation exists for seed storage proteins both within and among *Arachis* species, including *A. hypogaea* (Cherry 1975; Klozova et al. 1983; Krishna and Mitra 1988; Bianchi-Hall et al. 1990; Singh et al. 1991b). Deviations among accessions of a single species – e.g., *A. correntina*, *A. cardenasii*, and *A. duranensis*

(Klozova et al. 1983; C. M. Bianchi-Hall, R.D. Keys, and H.T. Stalker, unpublished data, 1990) – have also been observed. Seed-to-seed variation, for example, within *A. batizocoi* accession GKBSPSc 30079, have caused further difficulty in the use of seed storage proteins in studies of biosystematic relationships.

In a study involving more than 100 accessions representing six of the seven *Arachis* sections, Stalker et al. (1990) found 17 highly polymorphic enzyme systems. Seed-to-seed variations within individual accessions were also observed for a large number of genotypes, with nearly 50% of the isozyme patterns for several accessions being different. This indicates that 1) accessions of diploid *Arachis* species are much more polymorphic than would be expected in a self-pollinating diploid species, and 2) a high level of variation is being preserved in species germplasm collections, at least in the collection at North Carolina State University where bees have been observed on plants in isolated plots. Even when variation was observed among accessions of a single species, the patterns were consistent enough that multivariate analyses clustered accessions generally as expected from sectional designations. However, a large amount of variation was observed among members of section *Erectoides* and several of these accessions were very similar to section *Arachis* taxa. Unexpectedly, *A. batizocoi* grouped by itself and was more distantly removed from other members of section *Arachis* than most taxa in other sections. On the basis of isozyme differentiation, the center of genetic diversity is the area of Mato Grosso, Brazil (Lacks et al. 1991); and the greatest probability of finding unique alleles to introgress into A. hypogaea is in the northern central, northeastern, southern and southeastern regions of Brazil. These four areas also correspond to regions where species outside section *Arachis* are found.

Germplasm Pools and Interspecific Hybridization Barriers

To more efficiently choose species for cultivar improvement programs, the germplasm resources of *Arachis* can be divided into gene pools. The primary gene pool consists of the cultivated species *A. hypogaea* and the closely related tetraploid *A. monticola*. Hybrids within and between these species are completely fertile. The secondary gene pool consists of A and B-genome diploid species of section *Arachis*. Interspecific hybrids have been reported between *A. hypogaea* and most of the taxa in the secondary gene pool (for reviews, see Stalker and Moss 1987; Singh et al. 1991a; Stalker et al. 1991a). The tertiary gene pool consists of *A. glandulifera* Stalker of section *Arachis* and species in the remaining six sections of the genus. Fertile hybrids have not been recovered between *A. hypogaea* and members of the tertiary gene pool.

Both pre- and postzygotic hybridization barriers restrict crossing between *Arachis* species of the genus. These barriers are most severe when taxa in the tertiary gene pool are used in crossing programs with *A. hypogaea*, but they also exist within the secondary gene pool. To fully understand the potential barriers that may prevent hybridization, a short review of embryo development is needed to clarify techniques which may be useful for rescue procedures. Fertilization usually occurs within 24 hours of pollination but may be delayed up to 2 days in some hybrid combinations (Rau et al. 1991). After fertilization, an intercalary meristem (located 1.5 to 3 mm from the basal ovule) becomes active about 2 days after pollination and commences a rapid growth phase at about day 4 (Pattee and Mohapatra 1987). Synchronous with the rapid growth phase, the embryo continues growth until reaching a four-tier stage and then becomes quiescent and does not resume growth until after soil penetration (Pattee and Mohapatra 1987). Thus, several critical stages exist during embryo development that may influence successful hybridization, including 1) fertilization, 2) early cell division, 3) resumption of growth after soil penetration, 4) differentiation into a heart-shaped embryo, and 5) later embryo development.

Although fertilization may be restricted in wide crosses (Sastri and Moss 1982), it is believed to have limited importance for most crosses. However, the application of mentor pollen or gibberellic acid can increase the percentage of pegging (Sastri and Moss 1982; Stalker et al. 1987). Lu et al. (1990) also showed that several perennial *Arachis* species have smaller stigmas that are surrounded by a protective ring of hairs, as opposed to annuals, which have larger stigmas and lack the ring of hairs. Thus, annuals can be more easily pollinated. Pegs commonly fail to reach the soil after fertilization (Johansen and Smith 1956; Sastri and Moss 1982; Halward and Stalker 1987), and embryo abortion often occurs within 10 days after pollination. Pattee and Stalker (1991) reported reciprocal differences in *A. hypogaea* crosses where *A. stenosperma* Greg. et Greg. *nom. nud.* females had many unfertilized eggs, while other crosses resulted in early embryo abortion. Johansen and Smith (1956) observed in other crosses that abortion was due to retarded embryo and endosperm growth and subsequent death prior to embryotic differentiation. Ozias-Akins and Branch (1990) and Halward and Stalker (1987) reported partial seed maturation and subsequent degeneration of interspecific hybrid embryos.

To circumvent the above-mentioned barriers, growth regulators have been applied to reproductive tissues to induce pegging and/or embryo growth with some success (Sastri and Moss 1982; Mallikarjuna and Sastri 1985a). To rescue embryos before abortion, nurse cultures of 1 to 4-day old embryos with accompanying peg tissues have resulted in embryo growth, but not differentiation into heart-shaped embryos (Moss et al. 1988a; Pattee et al. 1988). Johnson (1981) concluded that in-vitro culture of very small embryos requires a two-step process in which ovules are cultured until they become large enough to remove the embryos, which are then cultured to generate plants. This procedure is now routinely used and plant recovery from some interspecific crosses via embryo culture is now possible (Mallikarjuna and Sastri 1985b; Stalker and Eweda 1988; Ozias-Akins and Branch 1990). The process of embryo development in groundnut is complex and at least under both photo (Zamski and Ziv 1976; Thompson et al. 1985) and hormonal control (Shushu and Cutter 1990). Major obstacles to recovering interspecific hybrids continue to be the difficulty of first obtaining heart-shaped embryos and then in-vitro root formation on shoot tissues produced after in-vitro embryo culture, although significant progress has been made in rooting during recent years (Moss et al. 1988b).

Germplasm Evaluation

Arachis species have been evaluated for proteins, oil percentage, fatty acids, nitrogen fixation capacity, forage potential, and other traits; but the greatest potential for major economic impact is for increasing disease and insect resistances in *A. hypogaea*. Monogenic dominant traits will be the easiest to transfer because they can be more easily selected during the hybrid generations when sterility causes a major bottleneck for obtaining large numbers of plants. At least two desirable traits with simple genetic inheritance [resistance to rust (Singh et al. 1984) and nematodes (Nelson et al. 1990)] have been reported in *Arachis*. However, utilizing most sources of resistances has been difficult because traits are under multigenic control.

The most important traits to be transferred to *A. hypogaea* worldwide include resistance to the leaf spots caused by *Cercospora arachidicola* and *Cercosporidium personatum*, and rust caused by *Puccinia arachidis*. Other diseases and insect pests may be severe in relatively isolated areas or occur sporadically on a wider scale. Many *Arachis* species have been evaluated for diseases (for reviews, see Subrahmanyam et al. 1985a; Wynne et al. 1991) and insects (for reviews, see Amin 1985; Lynch 1990). A list of resistances found in *Arachis* species is summarized in Table 2. Resistant species appear to be concentrated in sections *Rhizomatosae* and *Arachis*, but this may be partly an artifact due to biased sampling for evaluations. Few accessions collected since 1976 have been tested, and many more are yet to be evaluated. Fortunately, resistance has been reported for species in the secondary gene pool for most disease and insect pests evaluated, with exceptions being lesser corn stalk borer (*Elasmopalpus lignosellus*) and clump virus resistances. Further, several species in section *Arachis* have multiple resistances – e.g., *A. chacoense* for *C. arachidicola*, tomato spotted wilt virus, *P. arachidis*, nematode (*Meloidogyne arenaria*), thrips (*Frankliniella fusca*), corn earworm (*Helicoverpa zea*), and plant leaf hoppers (*Empoasca fabae*); *A. cardenasii* for *C. personatum*, tomato spotted wilt virus, *P. arachidis*, *Didymella arachidicola*, *M. arenaria*, *F. fusca*, *H. zea*, and *E. fabae*; *A. stenosperma* for *C. arachidicola*, *C. personatum*, *P. arachidis*, *F. fusca*, *E. fabae*, *H. zea*, and *M. arenaria*; and *A. batizocoi* for *D. arachidicola*, *P. arachidis*, *M. arenaria*, *E. fabae*, and *H. zea*.

Pathways to Germplasm Introgression

Several strategies have been used to utilize *Arachis* species for improving *A. hypogaea* (Moss 1985; Stalker and Moss 1987; Simpson 1991). Because hybrids can be obtained between the cultivated groundnut and members of section *Arachis*, species in this group have most frequently been used in hybridization programs directed at genetic improvement of *A. hypogaea*. However, even within this group, genetic recombination is restricted. Thus, obtaining fertile *A. hypogaea*-like progenies does not ensure gene introgression, and the quickest methods to obtain stable 40-chromosome plants may not be the best for recovering germplasm with potential agronomic value. To date, no diploid species is in the pedigree of a released cultivar. In large part this is because germplasm utilization of interspecific crosses is a two-step process, where 1) the trait of interest is incorporated into the *A. hypogaea* genome, which results in hybrid

Table 2. Sources of high levels of disease and insect resistances found in *Arachis species.*

	Evaluated	*Arachis monticola*	No. accessions in section[1] Amb.	Ara.	Cau.	Ere.	Ext.	Rhi.	Tri.	Unknown	Reference
					Diseases						
Cercospora arachidicola	93	-	-	1	-	2	3	24	-	-	Abdou et al. 1974
Cercospora arachidicola	4	-	-	2	-	-	-	1	-	-	Subrahmanyam et al. 1980
Cercosporidium personatum	93	-	-	1	-	2	3	14	-	-	Abdou et al. 1974
Cercosporidium personatum	95	-	-	15	4	12	2	50	1	-	Subrahmanyam et al.1985b
Cylindrocladium black rot	19	1	-	12	-	-	-	-	-	-	Fitzner et al. 1985
Didymella arachidicola	50	1	1	23	1	4	1	1	-	-	Subrahmanyam et al. 1985c
Puccinia arachidis	61	-	-	18	-	4	1	34	1	-	Subrahmanyam & Moss 1983
Nematodes											
Meloidogyne arenaria	36	-	-	11	-	1	-	14	-	9	Holbrook & Noe 1990
M. arenaria	116	-	4	23	-	1	-	12	-	7	Nelson et al. 1989
M. hapla	33	-	-	-	-	-	-	1	-	-	Banks 1969
M. hapla	?	-	-	-	-	-	-	-	-	4	Castillo et al. 1973
M. hapla	3	-	-	3	-	-	-	-	-	-	Nelson et al. 1989
Viruses											
Clump	38	-	-	-	-	-	-	-	-	1	ICRISAT 1985
Mottle	90	-	-	4	1	4	-	39	-	-	Demski & Sowell 1981
Mottle	?	-	-	3	-	-	-	3	-	-	Melouk et al. 1984
Mottle	50	-	1	1	-	-	-	-	-	-	Subrahmanyam et al. 1985a
Ringspot	?	-	-	1	-	-	1	1	-	5	Klesser 1965
Rosette	11	-	-	-	1	-	-	1	-	-	Gibbons 1969
Rosette	7	-	-	1	-	1	-	-	-	-	Wynne et al. 1991
Stripe	8	-	-	1	-	-	-	3	-	-	Culver & Sherwood 1987
Stunt	90	-	-	3	1	4	-	39	-	-	Hebert & Stalker 1981
Tomato spotted wilt	42	-	1	3	-	-	-	-	-	-	Subrahmanyam et al. 1985a
					Insects						
Aphis craccivora	7	-	-	4	-	1	-	-	-	3	Amin 1985; ICRISAT 1990
Elasmopalpus lignosellus	27	-	-	-	-	-	-	-	-	-	Stalker et al. 1984
Empoasca fabae	53	1	2	12	1	7	1	23	1	-	Stalker & Campbell 1983
Frankliniella fusca	53	-	2	11	-	9	1	25	1	-	Stalker & Campbell 1983
F. schultzei	?	-	-	1	-	-	-	-	1	-	Amin 1985
Helicoverpa zea	53	-	2	8	1	6	1	12	1	-	Stalker & Campbell 1983
Scirtothrips dorsalis	?	-	-	2	-	-	-	-	-	-	Amin 1985
Spodoptera frugiperda	14	-	-	4	-	1	-	1	-	-	Lynch et al. 1981
S. litura	22	-	-	1	-	-	-	1	-	4	ICRISAT 1990
Tetranychus tumidellus	54	-	-	-	1	-	1	1	-	-	Leuck & Hammons 1968
T. urticae	112	-	-	3	1	1	-	19	-	-	Johnson et al. 1977

1. Amb. = *Ambinervosae*; Ara. = *Arachis*; Can. = *Caulorhizae*; Ere. = *Erectoides*; Ext. = *Extranervosae*; Rhi. = *Rhizomatosae*; Tri. = *Triseminalae*.

derivatives with many undesirable characteristics, and 2) a breeding program to increase yield and quality is then necessary for cultivar development. A discussion of available methods to introgress germplasm will illustrate some of the difficulties and potentials for eventually using all the genetic resources available in the genus.

Direct hybridization

Direct hybridization is possible between *A. hypogaea* and approximately 25 species. Because *A. hypogaea* and *A. monticola* (the same biological species even though it represents a unique morphological type) are cross compatible at the same ploidy level and produce fertile hybrids, *A. monticola* can easily be used as a parent in a cultivar improvement program. This species is low yielding, but resistant to cylindrocladium black rot (Fitzner et al. 1985), *D. arachidicola* (Subrahmanyam et al. 1985c), and *E. fabae* (Stalker and Campbell 1983). Two cultivars have been released with *A. monticola* in their pedigree (Hammons 1970; Simpson and Smith 1974).

Direct hybridization is also possible between *A. hypogaea* and A or B-genome species of section *Arachis* and this produces true interspecific hybrids. The first hybrid between *A. hypogaea* and a wild diploid species was reported in 1951 between the cultigen and *A. villosa* var *correntina* (Krapovickas and Rigoni 1951). *Arachis hypogaea* has since been hybridized with at least 18 species of section *Arachis* (for review, see Stalker and Moss 1987; Stalker et al. 1991a). Although the resulting triploids are mostly sterile, seeds have been produced on plants of several hybrid combinations, presumably due to unreduced gametes (Simpson and Davis 1983; Singh and Moss 1984). Fertility in hybrids is more often restored after colchicine treatment of vegetative plant parts. Even though the resulting hexaploids ($2n = 6x = 60$) may have many univalents in pollen mother cells, selfed plants usually remain at the 60-chromosome level. For these hexaploids to be useful for germplasm enhancement of *A. hypogaea*, the ploidy must be lowered to 40 chromosomes. Theoretically, this can be achieved 1) directly via $6x \times 2x$ crosses, but this has been very difficult to achieve (Halward and Stalker 1987); 2) by backcrossing 6x plants with the 4x *A. hypogaea*, thus producing another mostly sterile generation at the pentaploid level; or 3) by selfing hexaploids and anticipating chromosome loss to the tetraploid level. Forty-chromosome progenies derived from hexaploid hybrids have been reported for several diploid species (Spielman et al. 1979; Stalker et al. 1979; Simpson and Davis 1983; Stalker 1984; Moss 1985; Singh and Moss 1982; Simpson 1991). Many advanced generation populations are being evaluated for agronomic traits including lines with both high yield and disease resistance (for reviews, see Stalker and Moss 1987; Moss et al. 1989; Singh et al. 1991a). The key to germplasm enhancement in the future will be inducing recombination between the genomes of *A. hypogaea* and diploid *Arachis* species (which is currently an unpredictable event) rather than simply producing interspecific hybrids.

To better understand the potential of utilizing the triploid-hexaploid pathway for crop improvement, the following example may be instructive. A single cross between *A. hypogaea* subsp *fastigiata* var *fastigiata* line × *A. cardenasii* accession (GKP 10017) was produced by J. Smartt in the mid-1960s. The triploid hybrid was then treated with colchicine to produce a fertile hexaploid plant that was self-pollinated. After five selfing generations (possibly more, but records are unavailable), a morphologically variable population was analyzed for ploidy levels at which time all plants were either at or near the tetraploid level (Stalker et al. 1979). Hybrid derivatives from this population have since been identified with very high levels of resistance to nematodes (M.K. Beute and H.T. Stalker, unpublished data, 1990), *C. arachidicola* (Stalker 1984), rust (Moss 1985), *C. personatum* (Moss 1985), leaf hopper (Stalker and Campbell 1983), corn earworm (Stalker and Campbell 1983), and southern corn rootworm (H.T. Stalker, unpublished data 1991). Other lines from the population had high yields (Guok et al. 1986) and, after being initiated into a recurrent selection program, three lines were competitive with high yielding cultivars in the North Carolina-Virginia production area of the USA. Halward et al. (1991b) reported that the high yielding populations continue to have significant amounts of variation after two cycles of recurrent selection, thus additional progress for increasing yield should be possible. Isozyme analyses of hybrid derivatives from this same cross have also shown banding patterns not common to either parent (G. Lacks and H.T. Stalker, unpublished data, 1990), which implies that 1) structural genes conferring disease and insect resistance and conditioning yield were transferred to *A. hypogaea* along with 2) unknown factors possibly affecting gene regulation of the *A. hypogaea* genome. The important point is that recombination occurred between *A. hypogaea* and *A. cardenasii* during selfing generations, most likely at the hexaploid level. When other hexaploid hybrids have been backcrossed to *A. hypogaea* during the early generations of polyploidy in the program at North Carolina, they have not resulted in a significant amount of detectable recombination.

Autotetraploids and amphiploids

Autotetraploids and amphiploids of *Arachis* species can be produced before hybridizing with *A. hypogaea*. Crosses with the cultivated species are then all at the same ploidy level. This pathway has the important advantage of circumventing sterility in triploid, hexaploid, or pentaploid hybrids; thus, genes can be more quickly introgressed, especially for simply inherited dominant traits. While doubling the chromosome number of diploid accessions or interspecific hybrids from vegetative cuttings is difficult, colchicine treatment of seeds results in a high (around 20%) success rate, although plants sectoring for ploidy levels is a problem and cytological confirmation is necessary (Gardner and Stalker 1983). Further, when a combination of A and B-genome species are used to produce amphidiploids, interspecific hybrids with *A. hypogaea* are generally more fertile than when either genome is used alone (Singh 1986a, 1986b). Autotetraploids or amphidiploids with at least eight diploid species have been used to produce hybrids with *A. hypogaea* (Gardner and Stalker 1983; Singh 1986a, 1986b, 1988). Progenies with resistance to groundnut rust (Singh 1986a), *C. arachidicola* (Gardner and Stalker 1983), and possibly to the tomato spotted wilt virus (T. Clemente and H.T. Stalker, unpublished data 1990) have been found using these two cytological pathways. However, levels of leaf spot resistance (multigenic inherited trait) were not as high as expected from progenies involving two species (*A. stenosperma* and *A. chacoense*) each with high levels of resistance (Gardner and Stalker 1983). The autotetraploid and amphidiploid pathways are easier to manipulate for gene transfer to *A. hypogaea* but also have disadvantages including polyploid identification, low vigor in many polyploid plants (especially for autotetraploids), few seeds are produced on hybrids with *A. hypogaea*, and, most importantly, they are believed to have restricted recombination between the *A. hypogaea* and wild species genomes.

Intersectional hybrids

Intersectional hybrids in the genus are very difficult to obtain (Gregory and Gregory 1979). Further, using specialized techniques such as mentor pollen, in-vitro fertilization, or growth regulator treatments have been mostly unsuccessful for obtaining hybrids with *A. hypogaea* (Mallikarjuna and Sastri 1985a, 1985b). Attempts to enhance introgression by using complex hybrids have also been unsuccessful (Stalker 1981, 1985). Embryo rescue techniques have resulted in at least one hybrid between *A. monticola* and a section *Rhizomatosae* accession (Sastri and Moss 1982), and between *A. hypogaea* and *A. villosulicarpa* from section *Extranervosae* (Moss et al. 1988b). Because fertility has not been restored in these or other intersectional hybrids, the potential of utilizing species outside section *Arachis* are currently unrealized.

Future Directions

A seemingly unlimited amount of work needs to be completed in *Arachis* to fully utilize the available genetic resources. While the number of accessions in germplasm collections have greatly increased during recent years, additional field collection is needed in South America. Maintenance of the species germplasm remains a labor-intensive and costly venture. Most accessions need to be characterized morphologically and for agronomic traits, and a taxonomic treatment of the genus remains a high priority. Fortunately, most reports of evaluations have included collector's or U.S. plant inventory numbers so resistant accessions can be identified in the literature.

Several traits with agronomic value have been identified in many species of the genus, but introgressing resistances into *A. hypogaea* has been difficult. Breeding acceptable market types from interspecific hybrid derivatives is progressing at a relatively slow pace, and efforts should continue in this area. Producing interspecific hybrids with species from section *Arachis* will continue to be the most fruitful area for germplasm enhancement, but even here, barriers exist that restrict gene transfer. Although reciprocal hybrids are sometimes difficult or nearly impossible to produce, a goal of several programs is to create a series with wild species cytoplasms containing the *A. hypogaea* nuclear genome. Studies are needed to understand reproductive development so that methods can be developed to obtain desired hybrids and to utilize the germplasm resources that are related to *A. hypogaea*.

Even after F_1 interspecific hybrids are obtained, inducing recombination between the genomes of the different species is critical. Evaluations to determine the 'best' pathway for introgression would greatly facilitate use of *Arachis* germplasm, especially in section *Arachis*, and this may now be possible with the use of molecular markers. Large numbers of advanced generation interspecific hybrid populations must be developed when attempting to transfer traits with complex inheritance; and extensive field evaluations of these hybrid derivatives will be necessary. Even the first step to introgress desirable traits is a long-term process, and cooperative efforts with breeders, pathologists, and others will be crucial for exploiting hybrids for cultivar improvement. A growing number of reports indicate that germplasm from *Arachis* species has been introgressed into the *A. hypogaea* genome and past cytogenetic and breeding efforts are just beginning to fulfill their potential for improvement of the cultivated groundnut.

References

Abdou, Y.A.M., Gregory, W.C., and Cooper, W.E. 1974. Sources and nature of resistance to *Cercospora arachidicola* Hori and *Cercosporidium personatum* (Berk. and Curt.) Deighton in *Arachis* species. Peanut Science 1:6-11.

Amin, P.W. 1985. Resistance of wild species of groundnut to insect and mite pests. Pages 57-60 *in* Proceedings of an International Workshop on Cytogenetics of *Arachis*, 31 Oct-2 Nov 1983, ICRISAT Center, India. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Banks, D.J. 1969. Breeding for northern root-knot nematode, *Meloidogyne hapla*, resistance in peanuts. Proceedings of American Peanut Research and Education Association 1:23-28.

Bianchi-Hall, C.M., Keys, R.D., and Stalker, H.T. 1990. Analysis of seed storage proteins in *Arachis* species using SDS-PAGE electrophoresis. Proceedings of American Peanut Research and Education Society 22:26. (Abstract.)

Cameron, D.G., Jones, R.M., Wilson, G.P.M., Bishop, H.G., Cook, B.G., Lee, G.R., and Lowe, K.F. 1989. Legumes for heavy grazing in coastal subtropical Australia. Tropical Grasslands 23:153-161.

Castillo, M.B., Morrison, L.S., Russell, C.C., and Banks, D.J. 1973. Resistance to *Meloidogyne hapla* in peanut. Journal of Nematology 5:281-285.

Cherry, J.P. 1975. Comparative studies of seed proteins and enzymes of species and collections of *Arachis* by gel electrophoresis. Peanut Science 2:57-65.

Culver, J.N., and Sherwood, J.L. 1987. Resistance to peanut stripe virus in *Arachis* germ plasm. Plant Disease 71:1080-1082.

Demski, J.W., and Sowell, G., Jr. 1981. Resistance to peanut mottle virus in *Arachis* spp. Peanut Science 8:45-47.

Fitzner, M.S., Alderman, S.C., and Stalker, H.T. 1985. Greenhouse evaluation of cultivated and wild peanut species for resistance to Cylindrocladium black rot. Proceedings of American Peanut Research and Education Society 17:28. (Abstract.)

Gardner, M.E.B., and Stalker, H.T. 1983. Cytology and leafspot resistance of section *Arachis* amphidiploids and their hybrids with *Arachis hypogaea*. Crop Science 23:1069-1074.

Gibbons, R.W. 1969. Groundnut rosette research in Malawi. Pages 1-8 *in* Proceedings of the Third Eastern African Cereals Research Conference, Mar 1969, Zambia and Malawi. Lilongwe, Malawi: Ministry of Agriculture and Natural Resources.

Gregory, M.P., and Gregory, W.C. 1979. Exotic germ plasm of *Arachis* L. interspecific hybrids. Journal of Heredity 70:185-193.

Gregory, W.C., Gregory, M.P., Krapovickas, A., Smith, B.W., and Yarbrough, J.A. 1973. Structures and genetic resources of peanuts. Pages 47-133 *in* Peanuts – culture and uses. Stillwater, Oklahoma, USA: American Peanut Research and Education Association.

Guok, H.P., Wynne, J.C., and Stalker, H.T. 1986. Recurrent selection within a population from an interspecific peanut cross. Crop Science 26:249-253.

Halward, T.M., and Stalker, H.T. 1987. Incompatibility mechanisms in interspecific peanut hybrids. Crop Science 27:456-460.

Halward, T.M., Stalker, H.T., LaRue, E.A., and Kochert, G.D. 1991a. The use of single-primer DNA amplifications in genetic studies of peanut. Page 54 in Abstracts of the Symposium on Plant Breeding in the 1990s. Research Report no. 130. Raleigh, North Carolina, USA: North Carolina State University.

Halward, T.M., Wynne, J.C., and Stalker, H.T. 1991b. Recurrent selection progress in a population derived from an interspecific peanut cross. Euphytica 52:79-84.

Hammons, R.O. 1970. Registration of Spancross peanuts. Crop Science 10:459.

Hebert, T.T., and Stalker, H.T. 1981. Resistance to peanut stunt virus in cultivated and wild *Arachis* species. Peanut Science 8:45-47.

Hermann, F.J. 1954. A synopsis of the genus *Arachis*. Agricultural Monograph no. 19. Washington, D.C., USA: U.S. Government Printing Office.

Holbrook, C.C., and **Noe, J.P.** 1990. Resistance to *Meloidogyne arenaria* in *Arachis* spp and the implications on development of resistant peanut cultivars. Peanut Science 17:35-38.

ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1985. ICRISAT annual report 1984. Patancheru, A.P. 502 324, India: ICRISAT.

ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1990. ICRISAT annual report 1989. Patancheru, A.P. 502 324, India: ICRISAT.

Johansen, E.L., and **Smith, B.W.** 1956. *Arachis hypogaea* × *Arachis diogoi*. Embryo and seed failure. American Journal of Botany 43:250-258.

Johnson, B.B. 1981. Embryo-ovule culture. Environmental and Experimental Botany 21:439. (Abstract.)

Johnson, D.R., **Wynne, J.C.**, and **Campbell, W.V.** 1977. Resistance of wild species of *Arachis* to the twospotted spider mite, *Tetranychus urticae*. Peanut Science 4:9-11.

Klesser, P.J. 1965. Groundnut ringspot virus – a new sap-transmissible virus of *Arachis hypogaea* and *A. monticola*. South African Journal of Agricultural Science 9:711-720.

Klozova, E., **Turkova, V.**, **Smartt, J.**, **Pitterova, K.**, and **Svachulova, J.** 1983. Immunochemical characterization of seed proteins of some species of the genus *Arachis* L. Biologia Plantarum (Praha) 25:201-208.

Kochert, G., **Halward, T.**, **Branch, W.D.**, and **Simpson, C.E.** 1991. RFLP variability in peanut (*Arachis hypogaea* L.) cultivars and wild species. Theoretical and Applied Genetics 81:565-570.

Krapovickas, A. 1969. Evolution of the genus *Arachis*. Seminario Advanzado de Genetica Agricola para America Latina, Maracay, Venezuela SAGA/B(d):1-4.

Krapovickas, A. 1973. Evolution of the genus *Arachis*. Pages 135-151 *in* Agricultural genetics: selected topics (Moav, R., ed.). Jerusalem, Israel: National Council for Research and Development.

Krapovickas, A. 1990. A taxonomic summary of the genus *Arachis* as proposed by A. Krapovickas 28 Feb 1989. Page 9 in International Crop Network Series. 2. Report of a workshop on the Genetic Resources of Wild *Arachis* species, 29 Feb-2 Mar 1989, Cali, Colombia, including preliminary descriptors for *Arachis* (IBPGR/ICRISAT). Rome, Italy: International Board for Plant Genetic Resources.

Krapovickas, A., and **Rigoni, V.A.** 1951. Estudios citologicas en el genero *Arachis*. (In Es.) Revista de Investigaciones Agricolas 5:289-293.

Krishna, T.G., and **Mitra, R.** 1988. The probable genome donors to *Arachis hypogaea* L. based on arachin seed storage protein. Euphytica 37:47-52.

Lacks, G.D., **Stalker, H.T.**, and **Murphy, J.P.** 1991. Patterns of isozyme variation among *Arachis* species. Page 71 *in* Abstracts of the Symposium on Plant Breeding in the 1990s. Research Report no. 130. Raleigh, North Carolina, USA: North Carolina State University.

Leuck, D.B., and **Hammons, R.O.** 1968. Resistance of wild peanut plants to the mite *Tetranychus tumidellus*. Journal of Economic Entomology 61:687-688.

Lu, J., **Mayer, A.**, and **Pickersgille, B.** 1990. Stigma morphology and pollination in *Arachis* L. (Leguminosae). Annals of Botany 66:73-82.

Lynch, R.E. 1990. Resistance in peanut to major arthropod pests. Florida Entomologist 73:422-445.

Lynch, R.E., **Branch, W.D.**, and **Gardner, J.W.** 1981. Resistance of *Arachis* species to the fall armyworm, *Spodoptera frugiperda*. Peanut Science 8:106-108.

Mallikarjuna, N., and **Sastri, D.C.** 1985a. Utilization of incompatible species in *Arachis*: sequential hormone applications. Pages 147-151 *in* Proceedings of an International Workshop on Cytogenetics of *Arachis*, 31 Oct–2 Nov 1983, ICRISAT Center, India. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Mallikarjuna, N., and **Sastri, D.C.** 1985b. *In vitro* culture of ovules and embryos from some incompatible interspecific crosses in the genus *Arachis* L. Pages 153-163 *in* Proceedings of an International

Workshop on Cytogenetics of *Arachis*, 31 Oct–2 Nov 1983, ICRISAT Center, India. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Melouk, H.A., Sanborn, M.R., and **Banks, D.J.** 1984. Sources of resistance to peanut mottle virus in *Arachis* germplasm. Plant Disease 68:563-564.

Moss, J.P. 1985. Breeding strategies for utilization of wild species of *Arachis* in groundnut improvement. Pages 93-99 *in* Proceedings of an International Workshop on Cytogenetics of *Arachis*, 31 Oct–2 Nov 1983, ICRISAT Center, India. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Moss, J.P., Dutt, N.R.G., and **Ligamaneni, A.** 1988b. Root induction on *in vitro* grown shoots of *Arachis* species and a hybrid. International *Arachis* Newsletter 4:25-26.

Moss, J.P., Rao, V.R., and **Gibbons, R.W.** 1989. Evaluating the germplasm of groundnut (*Arachis hypogaea*) and wild *Arachis* species at ICRISAT. Pages 212-234 *in* The use of plant genetic resources (Brown, A.H.D., Frankel, O.H., Marshall, D.R., and Williams, J.T., eds.). Cambridge, UK: Cambridge University Press.

Moss, J.P., Stalker, H.T., and **Pattee, H.E.** 1988a. Embryo rescue in wide crosses in *Arachis*. 1. Culture of ovules in peg tips of *Arachis hypogaea*. Annals of Botany 61:1-7.

Murty, U.R., and **Jahnavi, M.R.** 1986. The 'A' genome of *Arachis hypogaea* L. Cytologia 51:241-250.

Nelson, S.C., Simpson, C.E., and **Starr, J.L.** 1989. Resistance to *Meloidogyne arenaria* in *Arachis* spp germplasm. Journal of Nematology 21:654-660.

Nelson, S.C., Starr, J.L., and **Simpson, C.E.** 1990. Expression of resistance to *Meloidogyne arenaria* in *Arachis batizocoi* and *A. cardenasii*. Journal of Nematology 22:423-425.

Ozias-Akins, P., and **Branch, W.D.** 1990. Incompatibility during late embryogeny in some crosses of *Arachis hypogaea* × *A. stenosperma* and the utility of three tissue culture methods for hybrid rescue. Proceedings of American Peanut Research and Education Society 22:51. (Abstract.)

Pattee, H.E., and **Mohapatra, S.C.** 1987. Anatomical changes during ontogeny of the peanut (*Arachis hypogaea* L.) fruit: mature megagametophyte through heart-shaped embryo. Botanical Gazette 148:156-164.

Pattee, H.E., and **Stalker, H.T.** 1991. Observations of reproductive efficiency in crosses between cv NC 6 and two *Arachis* species. Page 74 *in* Abstracts of the Symposium on Plant Breeding in the 1990s. Research Report no. 130. Raleigh, North Carolina, USA: North Carolina State University.

Pattee, H.E., Stalker, H.T., and **Moss, J.P.** 1988. Embryo rescue in wide crosses in *Arachis*. 2. Embryo development in cultured peg tips of *Arachis hypogaea*. Annals of Botany 61:103-112.

Prine, G.M., Dunavin, L.S., Glennon, R.J., and **Roush, R.D.** 1990. Registration of 'Arbrook' rhizoma peanut. Crop Science 30:743-744.

Prine, G.M., Dunavin, L.S., Moore, J.E., and **Roush, R.D.** 1986. Registration of 'Florigraze' rhizoma peanut. Crop Science 26:1084-1085.

Rau, T.P.S., Stalker, H.D., and **Pattee, H.E.** 1991. Interspecific incompatibility in the genus *Arachis*. Proceedings of American Peanut Research and Education Society 23:22.

Sastri, D.C., and **Moss, J.P.** 1982. Effects of growth regulators on incompatible crosses in the genus *Arachis* L. Journal of Experimental Botany 53:1293-1301.

Shushu, D.D., and **Cutter, E.G.** 1990. Growth of the gynophore of the peanut *Arachis hypogaea*. 2. Regulation of growth. Canadian Journal of Botany 68:965-978.

Simpson, C.E. 1982. Collection of *Arachis* germplasm (1976-82). Plant Genetic Resources Newsletter 52:10-12.

Simpson, C.E. 1990. Collecting wild *Arachis* in South America: past and future. Pages 10-17 *in* International Ccrop Network Series. 2. Report of a Workshop on the Genetic Resources of Wild *Arachis* Species, 29 Feb-2 Mar 1989, Cali, Colombia, including preliminary descriptors for *Arachis* (IBPGR/ICRISAT). Rome, Italy: International Board for Plant Genetic Resources.

Simpson, C.E. 1991. Pathways for introgression of pest resistance into *Arachis hypogaea* L. Peanut Science 18:22-26.

Simpson, C.E., and **Davis, K.S.** 1983. Meiotic behavior of a male fertile triploid *Arachis* L. hybrid. Crop Science 25:581-584.

Simpson, C.E., and **Higgins, D.L.** 1984. Catalog of *Arachis* germplasm collections in South America, 1976–1983. Bulletin, Texas Agricultural Experiment Station no. MP-1570.

Simpson, C.E., and **Smith, O.D.** 1974. Tamnut 74. Bulletin, Texas Agricultural Experiment Station no. L-1348.

Singh, A.K. 1986a. Utilization of wild relatives in the genetic improvement of *Arachis hypogaea* L. 8. Synthetic amphiploids and their importance in interspecific breeding. Theoretical and Applied Genetics 72:433-459.

Singh, A.K. 1986b. Utilization of wild relatives in the genetic improvement of *Arachis hypogaea* L. 7. Autotetraploid production and prospects in interspecific breeding. Theoretical and Applied Genetics 72:164-169.

Singh, A.K. 1988. Putative genome donors of *Arachis hypogaea* (*Fabaceae*), evidence from crosses with synthetic amphiploids. Plant Systematics and Evolution 160:143-151.

Singh, A.K., and **Gibbons, R.W.** 1986. Wild species in crop improvement: groundnut – a case study. Pages 297-307 *in* Proceedings of the Symposium on Advances in Genetics and Crop Improvement, 27-29 Dec 1984, Meerut, India (Gupta, P.K., and Bahl, J.R., eds.). Meerut, Uttar Pradesh, India: Rastogi and Company.

Singh, A.K., and **Moss, J.P.** 1982. Utilization of wild relatives in genetic improvement of *Arachis hypogaea* L. Part 2. Chromosome complements of species in section *Arachis*. Theoretical and Applied Genetics 61:305-314.

Singh, A.K., and **Moss, J.P.** 1984. Utilization of wild relatives in genetic improvement of *Arachis hypogaea* L. VI. Fertility in triploids: cytological basis and breeding implications. Peanut Science 11:17-21.

Singh, A.K., Sivaramakrishnan, S., Mengesha, M.H., and **Ramaiah, C.D.** 1991b. Phylogenetic relations in section *Arachis* based on seed protein profile. Theoretical and Applied Genetics 82:593-597.

Singh, A.K., Stalker, H.T., and **Moss, J.P.** 1991a. Cytogenetics and use of alien genetic variation in groundnut improvement. Pages 65-77 *in* Chromosome engineering in plants: genetics, breeding and evolution (Tsuchiya, T., and Gupta, P.K., eds.). The Hague, Netherlands: Elsevier Science.

Singh, A.K., Subrahmanyam, P., and **Moss, J.P.** 1984. The dominant nature of resistance to *Puccinia arachidis* in certain wild *Arachis* species. Oleagineux 39:535-537.

Smartt, J., and **Stalker, H.T.** 1982. Speciation and cytogenetics in *Arachis*. Pages 21-49 *in* Peanut science and technology (Pattee, H., and Young, C., eds.). Yoakum, Texas, USA: American Peanut Research and Education Society.

Spielman, I.V., Burge, A.P., and **Moss, J.P.** 1979. Chromosome loss and meiotic behavior in interspecific hybrids in the genus *Arachis* L. and their implications in breeding for disease resistance. Zeitschrift für Pflanzenzuchtung 83:236-250.

Stalker, H.T. 1981. Hybrids in the genus *Arachis* between sections *Erectoides* and *Arachis*. Crop Science 21:359-362.

Stalker, H.T. 1984. Utilizing *Arachis cardenasii* as a source of cercospora leaf spot resistance for peanut improvement. Euphytica 33:529-538.

Stalker, H.T. 1985. Cytotaxonomy of *Arachis*. Pages 65-79 *in* Proceedings of an International Workshop on Cytogenetics of *Arachis*, ICRISAT Center, India. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Stalker, H.T. 1990. A morphological appraisal of wild species in section *Arachis* of peanuts. Peanut Science 17:117-122.

Stalker, H.T. 1991. A new species in section *Arachis* of peanuts with a D genome. American Journal of Botany 78:630-637.

Stalker, H.T., and **Campbell, W.V.** 1983. Resistance of wild species of peanut to an insect complex. Peanut Science 10:30-33.

Stalker, H.T., and **Dalmacio, R.D.** 1981. Chromosomes of *Arachis* species, section *Arachis*. Journal of Heredity 72:403-408.

Stalker, H.T., and **Dalmacio, R.D.** 1986. Karyotype analysis and relationships among varieties of *Arachis hypogaea*. Caryologia 51:617-629.

Stalker, H.T., and **Eweda, M.A.** 1988. Ovule and embryo culture of *Arachis hypogaea* and interspecific hybrids. Peanut Science 15:98-104.

Stalker, H.T., and **Moss, J.P.** 1987. Speciation, cytogenetics, and utilization of *Arachis* species. Advances in Agronomy 41:1-40.

Stalker, H.T., and **Wynne, J.C.** 1983. Photoperiodic response of peanut species. Peanut Science 10:59-62.

Stalker, H.T., Campbell, W.V., and **Wynne, J.C.** 1984. Evaluation of cultivated and wild peanut species for resistance to lesser cornstalk borer (Lepidoptera: Pyralidae). Journal of Economic Entomology 77:53-57.

Stalker, H.T., Dhesi, J.S., and **Parry, D.C.** 1991b. An analysis of the B genome species *A batizocoi* (*Fabaceae*). Plant Systematics and Evolution 174:159-169.

Stalker, H.T., Dhesi, J.S., Parry, D.C., and **Hahn, J.H.** 1991a. Cytological and interfertility relationships of *Arachis* section *Arachis*. American Journal of Botany 78:238-246.

Stalker, H.T., Jones, T.M., and **Murphy, J.P.** 1990. Isozyme variability among *Arachis* species. Proceedings of American Peanut Research and Education Society 22:50. (Abstract.)

Stalker, H.T., Seitz, M.H., and **Reece, P.** 1987. Effect of gibberellic acid on pegging and seed set in *Arachis* species. Peanut Science 14:21-25.

Stalker, H.T., Wynne, J.C., and **Company, M.** 1979. Variation in progenies of an *Arachis hypogaea* × diploid wild species hybrid. Euphytica 28:675-684.

Subrahmanyam, P., and **Moss, J.P.** 1983. Resistance to peanut rust in wild *Arachis* species. Plant Disease 67:209-212.

Subrahmanyam, P., Ghanekar, A.M., Nolt, B.L., Reddy, D.V.R., and **McDonald, D.** 1985a. Resistance to groundnut diseases in wild *Arachis* species. Pages 49-55 *in* Proceedings of an International Workshop on Cytogenetics of *Arachis*, 31 Oct–2 Nov 1983, ICRISAT Center, India. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Subrahmanyam, P., Mehan, V.K., Nevill, D.J., and **McDonald, D.** 1980. Research on fungal diseases of groundnut at ICRISAT. Pages 193-198 *in* Proceedings of the International Workshop on Groundnuts, 13–17 Oct 1980, ICRISAT Center, India. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Subrahmanyam, P., Moss, J.P.,McDonald, D., Rao, P.V.S., and **Rao, V.R.** 1985b. Resistance to leaf spot caused by *Cercosporidium personatum* in wild *Arachis* species. Plant Disease 69:951-954.

Subrahmanyam, P., Smith, D.H., and **Simpson, C.E.** 1985c. Resistance to *Didymella arachidicola* in wild *Arachis* species. Oleagineux 40:53-56.

Thompson, L.K., Ziv, M., and **Deitzer, G.F.** 1985. Photocontrol of peanut (*Arachis hypogaea* L.) embryo and ovule development *in vitro*. Plant Physiology 78:370-373.

Valls, J.F.M., Rao, V.R., Simpson, C.E., and **Krapovickas, A.** 1985. Current status of collection and conservation of South American groundnut germplasm with emphasis on wild species of *Arachis*. Pages 15-33 *in* Proceedings of an International Workshop on Cytogenetics of *Arachis*, 31 Oct–2 Nov 1983, ICRISAT Center, India. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Wynne, J.C., Beute, M.K., and **Nigam, S.N.** 1991. Breeding for disease resistance in peanut (*Arachis hypogaea* L.). Annual Review of Phytopathology 29:279-303.

Zamski, E., and **Ziv, M.** 1976. Pod formation and its geotropic orientation in peanut, *Arachis hypogaea* L., in relation to light and mechanical stimulus. Annals of Botany 40:631-636.

Groundnut Genetic Resources: Progress and Prospects

A.K. Singh[1], V. Ramanatha Rao[2] and M.H. Mengesha[1]

Abstract

*Progress during the past 11 years and future prospects of groundnut (*Arachis hypogaea*) genetic resources at ICRISAT are reviewed. The number of accessions in the ICRISAT gene bank have increased from 8500 to 13 460. However, many areas with limited cultivation but with extensive variability are yet to be covered. Most of the accessions have been characterized and evaluated for their reaction to diseases, insect pests, and other desirable characters, leading to identification of 506 useful genetic stocks. This information has been documented and is to be made available in a catalog. Most of the germplasm are conserved as pods or seeds in medium-term (4°C, 20% RH) and long-term (-20°C) storage conditions, while rhizomatous* Arachis *species are conserved as plants. ICRISAT serves as the world's largest repository of groundnut germplasm and has distributed 60 061 groundnut germplasm samples free of cost to the international scientific community involved in groundnut improvement worldwide.*

Despite significant progress, groundnut genetic resources activities still suffer from several limitations in assembly and characterization. The establishment of a groundnut genetic resources network is proposed to overcome many such limitations.

Résumé

Ressources génétiques de l'arachide—Progrès et possibilités : *Les auteurs examinent les progrès effectués depuis 11 ans et les possibilités d'avenir pour les ressources génétiques de l'arachide (*Arachis hypogaea*) à l'ICRISAT. Le nombre d'obtentions à la banque de gènes de l'ICRISAT a augmenté de 8500 à 13 460. Toutefois, il reste encore à couvrir bien des domaines où la culture est restreinte et la variabilité très étendue. La plupart des obtentions ont été caractérisées et évaluées d'après leurs réactions aux maladies, aux insectes ravageurs et d'autres caractéristiques souhaitables menant à identifier 506 souches génétiques utiles. Cette information a été documentée et sera distribuée dans un catalogue. La majeure partie des ressources génétiques a été conservée sous forme de gousses et de semences dans des conditions de stockage à moyen terme (4°C, 20% HR) et à long terme (–20°C), tandis que des espèces d'*Arachis *rhizomateuses ont été conservées sous forme de plants. L'ICRISAT joue le rôle du plus grand stock mondial des ressources génétiques d'arachide et il a distribué 60 061 échantillons de ressources génétiques d'arachides gratuitement à la communauté scientifique internationale qui s'intéresse à l'amélioration de l'arachide dans le monde entier.*

En dépît des progrès marqués, les activités des ressources génétiques de l'arachide subissent encore plusieurs limites. L'établissement d'un réseau de ressources génétiques de l'arachide est proposé pour surmonter un grand nombre de ces limites.

1. Germplasm Botanist, and Principal Germplasm Botanist and Program Leader, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, A.P. 502 324, India.

2. Genetic Diversity Officer, International Board for Plant Genetic Resources (IBPGR), Food and Agriculture Organization of the United Nations (FAO), via delle Sette Chiese 142, 00145 Rome, Italy.

ICRISAT Conference Paper no. CP 805.

Singh, A.K., Ramanatha Rao, V., and Mengesha, M.H. 1992. Groundnut genetic resources: progress and prospects. Pages 297–309 *in* Groundnut – a global perspective: proceedings of an international workshop, 25–29 Nov 1991, ICRISAT Center, India (Nigam, S.N., ed.). Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

The importance of genetic resources in crop improvement has been repeatedly emphasized (Hawkes 1981). In addition to its other mandate crops, the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), within the system of the International Agricultural Research Centers (IARCs), has global responsibility for collection, characterization, conservation, distribution, and utilization of groundnut (*Arachis hypogaea*) and other *Arachis* species germplasm. To achieve these objectives, the Genetic Resources Unit (GRU) at ICRISAT collaborates with various international and national programs involved with groundnut. It acts as the world's largest repository for more than 13 000 accessions of cultivated and wild *Arachis* species, and provides these basic genetic stocks to the international scientific community for further improvement of groundnut.

The range of genetic diversity available at ICRISAT in the form of cultivated groundnut and wild *Arachis* species is much wider than is generally thought. Nevertheless, it reveals a relatively limited representation from primary and secondary centers of diversity in South America and areas of early introductions in Africa and Asia. These areas may contain much more genetic diversity that may be lost through further expansion of improved cultivars and encroachment of modern civilization in remote areas. There is an urgent need to collect and assemble more germplasm from these priority areas to preserve genetic diversity of *Arachis* species. Significant progress in germplasm evaluation has been made in the last decade, leading to the identification of a number of lines with desirable traits and sources of resistance to both biotic and abiotic production constraints (Amin et al. 1985; Mehan 1989; Subrahmanyam et al. 1990). However, there are many lacunae, such as incomplete evaluation of the useful germplasm, restricting utilization of these sources, and lack of detailed knowledge on the useful gene(s), which are essential for selection of appropriate breeding strategies for their effective utilization. Similarly, extensive work has been done on evolutionary relationships between *Arachis* species and cultivated groundnut (Smartt et al. 1978; Singh 1988), but the taxonomy and the nomenclature of *A. hypogaea* and species of the genus *Arachis* still remain confusing (Resslar 1980). It is obvious that much more needs to be done to fully understand and utilize the available genetic diversity. This paper attempts to review the status of groundnut germplasm at ICRISAT and the limitations that must be overcome to improve utilization of the *Arachis* germplasm.

Sources of Genetic Diversity

The main sources of genetic diversity in groundnut include:

- The primary gene pool, consisting of landraces of cultivated groundnut from the primary center of origin and diversity in South America (Fig. 1) and Africa, the cultivars and breeding materials developed in various groundnut-growing countries, and the freely cross-compatible wild tetraploid species *A. monticola*.
- The secondary gene pool, consisting of species that are cross-compatible with *A. hypogaea* despite ploidy differences and classified in section *Arachis* with *A. hypogaea*.
- The tertiary gene pool, consisting of the other *Arachis* species that are cross-incompatible or weakly cross-compatible with *A. hypogaea* and classified into six other sections.

South America is the center of origin for the genus *Arachis*. The wild *Arachis* species are found in Argentina, Brazil, Bolivia, Paraguay, and Uruguay (Valls et al. 1985). Efforts to collect and conserve this genetic diversity have been made by scientists in countries having diversity and groundnut cultivation. The genetic diversity in South America has been continuously eroded by deforestation and political disturbances, and that, in Africa, by natural hazards, introduction of improved cultivars, and nonmaintenance of old collections and landraces.

Collection and assembly of germplasm at ICRISAT

Collection and assembly of groundnut genetic resources at ICRISAT commenced in 1976 with the establishment of the groundnut improvement program. By 1980, with the establishment of GRU, 8500 accessions were assembled from 49 countries (Rao 1980). Of these, 7703 accessions were transferred from various research institutions and gene banks (Table 1). Since 1980 we have added 1536 more accessions from collection expeditions by ICRISAT staff in 19 countries and assembled another 3102 accessions by request and/or as donation from 47 organizations (Tables 1 and 2). At present the ICRISAT gene bank contains 13 460 accessions, including 197 wild *Arachis* species accessions from 89 countries (Table 3). The collections are nondiscriminatory in the sense that both landraces and materials developed

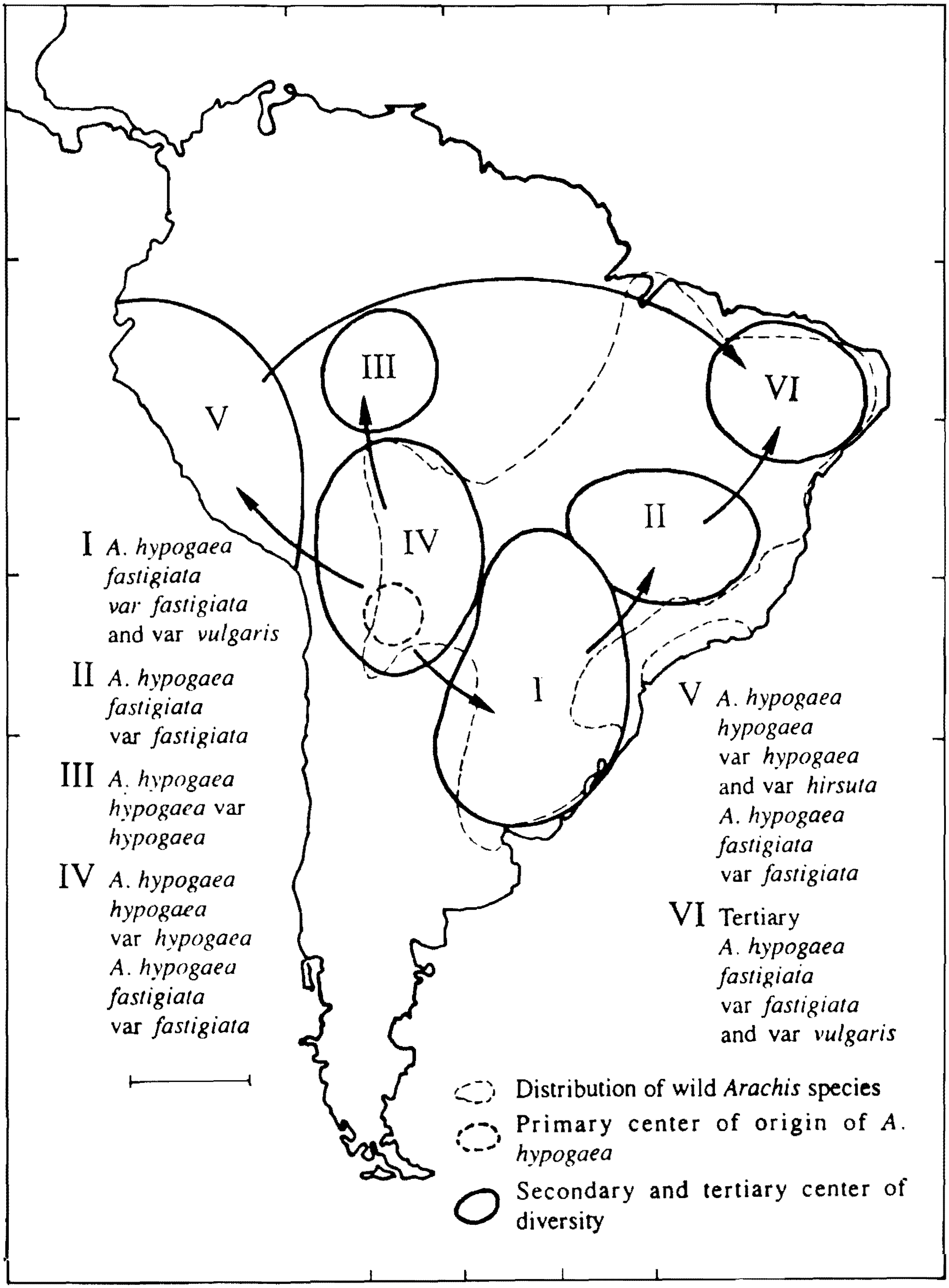


Figure 1. Centers of origin and diversity of cultivated groundnut (*Arachis hypogaea*). (Source: Gregory and Gregory 1976.)

Table 1. List of countries with number of institutions and *Arachis* germplasm accessions donated to ICRISAT.

	No. of institutions		No. of accessions	
Country	1980	1991	1980	1991
CIS (formerly USSR)	1	1	3	3
India	15	22	4 969	6 367
Indonesia	0	1	0	57
Japan	3	2	74	75
Malawi	1	1	263	283
Netherlands	0	1	0	4
Nigeria	1	1	103	106
People's Republic of China	1	2	5	31
Puerto Rico	0	1	0	14
Senegal	1	2	16	701
South Africa	0	1	33	117
South Korea	0	1	0	69
Sri Lanka	0	1	0	1
Sudan	0	1	0	1
Surinam	0	1	0	2
Tanzania	0	1	0	39
Trinidad	0	1	0	1
UK	1	1	20	20
USA	5		5	2 066
3 447				
Zimbabwe	1	1	151	151
Unknown	0	0	0	1
Total	30	48	7 703	11 490

by breeders and/or released cultivars, and wild relatives from the genus *Arachis* are collected, since any present day genotype could contain gene(s) that may be of future value. These collections are summarized in Table 4 and are classified into the following categories:

Accession collection. These are collections with identity assembled from other agencies.

Named cultivars. These are the cultivars released by various public and private institutions.

Landraces. These are unknown old cultigens collected from farmers' fields.

Breeding lines. These are materials developed by breeders but not released as cultivars after incorporating desired traits.

Genetic stocks. These are genotypes identified as sources of resistances to diseases and insect pests and other desirable traits, including mutants and experimental material.

Table 2. Number of expeditions and *Arachis* samples collected by ICRISAT staff since 1980.

Country	No. of expeditions	No. of accessions	Date of expedition
Botswana	1	8	Mar 1985
Brazil	3	38[1]	Mar 1982
		73	Mar 1982
		41	Mar 1987
Gambia	1	8	Nov 1980
Ghana	1	34	Aug 1981
India	7	185	Nov 1981
		8	Oct 1982
		1	Nov 1983
		19	Oct 1984
		21	Oct 1986
		30	Nov 1986
		16	Nov 1987
		126	Dec 1987
Indonesia	1	75	Dec 1989
Malaysia	1	43	Mar 1980
Mali	2	5	Oct 1981
		146	Oct 1986
Mozambique	1	131	May 1981
Myanmar	2	4	Mar 1980
		44	Nov 1987
Nigeria	1	48	Sep 1983
Philippines	1	9	Apr 1981
Rwanda	1	1	Jul 1982
Sierra Leone	1	2	Sep 1983
South Africa	1	1	Apr 1982
Tanzania	3	15	Aug 1981
		96	Apr 1985
		7	Apr 1987
Uganda	1	96	Feb 1991
Zambia	1	80	Jun 1980
Zimbabwe	3	7	May 1982
		68	Apr 1985
		44	Apr 1988
Total	33	1530	

1. Wild *Arachis* spp accession.

Wild *Arachis* species. These are wild species belonging to the genus *Arachis*.

The assembly of such a large collection is an example of excellent international cooperation received from various international and national agencies. However, there have been several gaps, because of loss of collections in several African countries, difficulties experienced in exchange of germplasm from some quarters, resource constraints for obtaining infection-free material from areas of specific stresses,

Table 3. *Arachis* germplasm status at ICRISAT, 1991.

Status/ representation	No. of accessions			
	A. hypogaea		*Arachis* species	
	1980	1991	1980	1991
Total accessions conserved	8 194	13 460	97	195
No. of countries represented	49	89	2	6
Primary centers				
Argentina	293	405	18	34
Bolivia	85	272	18	35
Secondary centers				
Brazil	329	465	43	87
Paraguay	106	163	17	33
Peru	69	316	0	0
Uruguay	25	40	0	1
Tertiary centers				
Africa	1 745	3 179	0	0

Table 4. Status of various *Arachis* germplasm conserved.

Resource	1980	1991
Accessions	3 974	7 817
Landraces	2 461	5 146
Named cultivars	130	230
Breeding lines	3 783	4 553
Genetic stocks	60	131
Wild *Arachis* spp	97	195
Taxonomic representation:		
Section		
Arachis	8 194	12 044
Erectoides		21
Caulorhizae		2
Rhizomatosae		90
Extranervosae		2
Trisaminalae		1
Procumbansae		0
Interspecific derivatives		165
Unknown		1 651

and political instability in regions of diversity. Non-discriminatory collection by several collectors and frequent exchange of germplasm between gene banks without original passport information has added to the inclusion of many duplicates and samples mainly from major areas of cultivation with a narrow level of representation of geographic (agroclimatic) and genetic diversity (most samples are variants of same genotype). These lacunae should be avoided in future, assemblies and duplicates should be identified using appropriate techniques. According to the original priorities major areas have been explored extensively. However, a number of countries/regions with limited groundnut cultivation may still contain extensive variability and it is essential that these areas should be explored to make world collection more comprehensive. Table 5 lists ICRISAT collection priorities for the next 10 years. We would appreciate support from different national and international agencies to limit the erosion of groundnut genetic resources in these areas.

Table 5. ICRISAT collecting priorities for *Arachis* germplasm.

Regions	In 1980 countries/regions	In 1991 countries
Asia	Indonesia[1] Myanmar[1]	Cambodia India Laos People's Republic of China Thailand Vietnam
Meso America	Caribbean islands Central America Mexico	Mexico
West Africa	Gambia[1] Nigeria Senegal Burkina Faso	Cameroon Central African Republic Gabon
Southern & Eastern Africa	Mozambique[1]	Angola Madagascar Namibia
South America	Argentina Bolivia Brazil[1] Paraguay Peru	Argentina Bolivia Brazil (Northeast) Paraguay Peru Uruguay

1. Explored.

Characterization

The entire groundnut germplasm collection at ICRISAT, with the exception of a few recently collected or acquired accessions, has been characterized at ICRISAT Center, located at 18°N, 78°E at Patancheru, Andhra Pradesh, India, according to the Groundnut Descriptors (IBPGR/ICRISAT 1981). Accessions are characterized under rainfed conditions during the rainy season (June to October) and irrigated conditions during the postrainy season (November to April). The wide range of variation in morphoagronomic characters in these collections is shown in Table 6.

Further screening of groundnut germplasm to assess its potential for various specific traits, particularly its reaction to different biotic and abiotic stresses, is carried out in collaboration with various disciplines of the ICRISAT Legumes Program. The results of this screening are summarized in Table 7. In addition, we collaborate in multilocation germplasm evaluation with the National Bureau of Plant Genetic Resources (NBPGR) of the Indian Council of Agricultural Research (Thomas et al. 1989).

After systematic characterization and evaluation of available germplasm at ICRISAT there are still several limitations restricting its utilization to the fullest extent. For a number of accessions identified as sources of resistance to various fungal diseases or pests, a complete picture on their reaction to other important biotic and abiotic stresses is lacking. Other limitations in characterization are lack of multilocation evaluation, including the place of origin, and lack of uniformity in scales used to characterize quantitative traits. In addition, most of the desirable traits identified in various accessions have not been characterized either at the genetic or the molecular level. Lack of this information limits our understanding of gene action and selection of the most appropriate breeding strategy. Similar ranges of variability observed for quantitative traits in a number of accessions indicate the presence of duplicates that should be sorted out to make the available variability more specific and save space for more important accessions.

Documentation

The morphological and agronomic data are collected in the form of preharvest and postharvest observations (see standard descriptors). It is tabulated on separate sheets, along with the passport information. Information on 12 160 accessions (excluding the ones assembled recently) is documented on computer using the ICRISAT Data Management System (Estes and Rao 1989). This program provides the option for retrieving the information in full or part with desired time periods and combination of descriptors. Thus it fulfills the requirement of the user for specific information in specific combinations on specific accessions. Documentation is updated as characterization is completed on acquired accessions. The information is available on request.

GRU also maintains a set of catalogs as ready reference on the identity of many accessions and collection status of groundnut germplasm in several gene banks around the world. The ICRISAT groundnut germplasm catalog with information on passport and morphoagronomic features of 12 160 accessions is ready for publication. Although significant progress has been made in documentation since 1980, the system has some limitations: for example, incomplete documentation on reaction to major stresses, and on the expression of characteristic traits in different agroclimatic conditions (because of lack of feedback from users or due to usage of different scale and language).

Conservation

The gene bank established at ICRISAT in 1979 serves as one of the major repositories for the world collection of groundnut germplasm and other mandate crops. It was established with the understanding that temperature and moisture are the two key factors influencing seed viability and longevity during storage. Control of these factors can dramatically improve the longevity of seeds in storage. At ICRISAT, we store the groundnut germplasm in the form of pods and seeds in moisture-proof and temperature-proof containers. The storage environment is controlled for low temperature and humidity in accordance with the guidelines of the International Board for Plant Genetic Resources (IBPGR) (Mengesha et al. 1989).

Short-term chamber

The short-term chamber maintains a temperature of 18°C and 30% relative humidity (RH) and holds freshly harvested material until it is dried and prepared for subsequent transfer.

Table 6. Range of variation in cultivated groundnut observed at ICRISAT Center.

Character	Minimum	Maximum	Intermediate(s)
Life form	Annual	-	-
Growth habit	Erect	Procumbent	Decumbent
Branching pattern	Sequential	Alternate	Irregular
Stem pigmentation	Absent	Present	-
Stem hairiness	Glabrous	Woolly	Hairy, very hairy
Reproductive branch length	1 cm	10 cm	Continuous
No. of flowers/inflorescence	1	5	2, 3, 4
Peg color	Absent	Present	-
Standard petal color	Yellow	Garnet	Lemon yellow, light orange, orange, dark orange
Standard petal markings	Yellow	Garnet	Lemon yellow, light orange, orange, dark orange
Leaf color	Yellowish green	Dark green	Light green, green, bottle green
Leaflet length	17 mm	94 mm	Continuous
Leaflet width	7 mm	52 mm	Continuous
Leaflet L/W ratio	1	6	Continuous
Leaflet shape	Cuneate	Lanceolate	Obcuneate, elliptic
Hairiness of leaflet	Subglabrous	Profuse and long	Scarce and short, scarce and long, profuse and short
No. of seed/pod	1	5	2, 3, 4
Pod beak	Absent	Prominent	Slight, moderate
Pod constriction	Absent	Very deep	Slight, moderate, deep
Pod reticulation	Smooth	Prominent	Slight, moderate
Pod length	14 mm	65 mm	Continuous
Pod width	7 mm	20 mm	Continuous
Seed color pattern	One	Variegated	-
Seed color	Off white	Dark purple	Yellow, shades of tan, rose shades of red, grey-orange, shades of purple
Seed length	4 mm	23 mm	Continuous
Seed width	5 mm	13 mm	Continuous
100-seed mass	14 g	136 g	Continuous
Days to emergence	4	18	Continuous
Days to 50% flowering	17	54	Continuous
Days to maturity	75	>155	Continuous
Fresh seed dormancy	0 days	>66 days	Continuous
Oil content	31.8%	55.0%	Continuous
Protein content	15.5	34.2	Continuous

Table 7. Status of screening of *Arachis* germplasm at ICRISAT Center.

Specific trait	1980 No. screened	1980 No. identified	1991 No. screened	1991 No. identified	Reported by
Disease resistance					
Leaf spot	8000	5	9400	76 (26)[2]	G'nut Path[3]
Rust	8000	13	9400	141 (35)	
TSWV	-[1]	0	7400	23 (6)	
PMV	-	2	1800	2 (2)	
Aflatoxin	-	3	582	17 (4)	
Pod rot	2000	6	3222	24 (6)	
Pest resistance					
Thrips	-	3	5000	14 (7)	G'nut Ent[4]
Jassids	-	5	6500	30 (7)	
Termites	-	6	520	20 (6)	
Aphids	-	1	300	4 (1)	
Leaf miner	-	6	930	18 (6)	
Multiple resistance	0	0	9400	85 (45)	
Abiotic stresses/nutrition					
Drought	0	0	742	38 (8)	G'nut Phy[5]
N fixation	-	3	342	4 (2)	
High oil	0	0	8868	44 (10)	Crop Qual[6]
High protein	0	0	8868	51	

1. Number of accessions screened not available.
2. Number of accessions commonly used in breeding programs are shown in parentheses.
3. G'nut Path = Groundnut Pathology.
4. G'nut Ent = Groundnut Entomology.
5. G'nut Phy = Groundnut Physiology.
6. Crop Qual = Crop Quality.

Table 8. Status of *Arachis* germplasm conservation at ICRISAT Center.

Status	No. of accessions conserved/conditions			
		Pod		Seed
	Plant natural	Short-term	Medium-term	Long-term
1980	0	6 791	8 291	0
1991	90	1 300	12 160	774

Medium-term chamber

The medium-term chamber has rooms maintained at 4°C and 20% RH, and conserves pods of 13 000 accessions.

Long-term chamber

The long-term chamber has rooms maintained at -20°C to store base germplasm and duplicates from other gene banks. At present, this conserves seeds of 1000 accessions in aluminium pouches. Table 8 summarizes the status of conserved germplasm.

Germplasm at ICRISAT has been carefully conserved to avoid genetic contamination, genetic drift, genetic shift, mechanical mixing, and loss of seed viability. Pathologists and virologists help us to stock the gene bank with disease-free seeds. However, we are short of resources for large-scale multiplication, and have limited opportunities for research on physical and chemical factors affecting viability and longevity of seeds in storage to make conservation more effective. It is possible to overcome some constraints such as space, low multiplication rate, and genetic damage in storage by using in-vitro techniques and cryopreservation.

Rejuvenation and Maintenance

Most of the groundnut accessions are seed producing and are maintained as seed. Rhizomatous accessions are maintained as plants in isolated concrete rings. Loss of seed viability and distribution of germplasm necessitate frequent rejuvenation and multiplication of large numbers of accessions. An accession is rejuvenated only when seed viability drops below 85% or the seed stock falls below 250 g. This activity is expensive and involves danger from genetic contamination, drift, and mechanical mixing. Hence, an attempt is being made to conserve a set of all accessions as base germplasm under long-term storage conditions, which will require more human and financial resources. All rejuvenation is done under ICRISAT conditions, rather than at the place of original collection (which may give an altogether different selection pressure); also the genetic stocks are not checked for the stability of their characteristic traits in each generation. Large multiplication and networking of genetic resource activities may help to overcome these problems.

Distribution

The distribution of seeds to scientists worldwide is one of the major responsibilities of the ICRISAT GRU. All exported material from ICRISAT is sent to the Indian Plant Quarantine Authority, which inspects it and grants phytosanitary certificates. Table 9 shows the number of accessions distributed by GRU since 1980. With each batch we also provide standard passport and other relevant information on identity, botanical group, and country of origin with remarks on any special features of the material. Distribution of groundnut germplasm has created an outstanding impact on research activities of various national agricultural research programs. However, vague requests, limited seed and pod quantity (because of large pod and seed size), and quarantine delays remain as constraints. Some of these limitations may be overcome by using in-vitro methods in conservation and exchange of germplasm.

Utilization

After centuries of natural and human selection, landraces and the wild relatives of groundnut have acquired resistance to specific biotic and abiotic stresses. This germplasm can be utilized as a source of resistances in breeding programs. At ICRISAT the available world germplasm has been evaluated for resistance to various groundnut diseases, insect pests, and environmental stresses, leading to the identification of a large number of genetic stocks (Table 7) (Amin et al. 1985; Mehan 1989; Subrahmanyam et al. 1990). GRU coordinates this activity to document

Table 9. ***Arachis*** **germplasm distributed by ICRISAT to various regions/organizations.**[1]

	No. of accessions					
	1980			1991		
Regions	*A. hypogaea*	*Arachis* species	Total	*A. hypogaea*	*Arachis* species	Total
Africa	724	4	728	8 225	14	8 967
America (North)	124	0	124	540	0	664
America (South)	103	0	103	204	0	307
Asia	9 080	9	9 089	39 227	308	48 624
Australia	42	0	42	87	0	129
Europe	69	0	69	853	2	924
Oceania	186	0	186	212	50	440
Individual	0	0	0	75	0	75
Research organization	0	0	0	4 529	0	4 529
Seed company	0	0	0	14	0	14
Total	10 328	13	10 341	49 348	322	60 061

1. Supplied also as cuttings and rhizomes.

complete information on each accession. ICRISAT scientists are also involved in introgression of specific resistance from several wild *Arachis* species and have generated much variability.

Significant progress in plant breeding has been made in the last decade but more exploitation of germplasm is needed. Incomplete evaluation of new sources, and their poor agronomic characteristics limit their use. The available interspecific variability has not been fully exploited either because of certain lacunae in the material generated or because of the shortage of expertise in the use of biotechnological techniques to transfer desirable traits. A more concerted effort in this area may provide benefits similar to those found for *Nicotiana tabacum*, *Medicago sativa*, and *Brassica* species.

Conclusions and Recommendations

During the last decade there has been good progress on the collection, characterization, and utilization of groundnut germplasm. However, there is still an urgent need to collect more germplasm from centers of diversity and areas of early introduction that are in danger from encroaching development. Landraces and wild *Arachis* species will be increasingly utilized if further evaluation can keep pace with collection and preliminary evaluation; otherwise these collections will not be properly utilized. Development of a uniform documentation system, and ready availability and exchange of information and germplasm would enhance their use by all scientists involved in crop improvement. Conservation of groundnut germplasm has received only limited research attention. In addition to conventional ex situ techniques, in-vitro conservation techniques will go a long way toward overcoming the present problems of conservation and distribution of germplasm. Immediate attention to the following recommendations will make conservation and utilization of groundnut germplasm more effective:

1. Strengthening resource centers in developing countries to facilitate collection, assembly, and evaluation in places of origin.
2. Setting up regional storage centers to conserve germplasm under natural or artificial conditions to reduce genetic variation or drift.
3. Increasing research into new techniques for conservation and distribution.
4. Developing rapid screening techniques to complete evaluation for reaction to virus diseases and fungal diseases such as *Aspergillus flavus*.
5. Including information on genetic characterization of useful traits and gene mapping in catalogs.
6. Transferring useful variability to good agronomic background.
7. Strengthening utilization of wild *Arachis* species through introgression into *A. hypogaea*, thus generating variability and broadening the genetic base of *A. hypogaea*.
8. Networking groundnut genetic resources activities to coordinate and to bring uniformity in characterization and documentation with facilities for international on-line searching.

Networking

Networking is a useful tool for improving the global status of crop genetic resources and bringing uniformity to various activities. We propose that curators, breeders, and researchers on *Arachis* present a plan of action to improve collection, conservation, and enhancement of available *Arachis* genetic resources. They can pool their resources and share the activities. A plan of action could be developed in a workshop convened jointly by ICRISAT and IBPGR during 1992, if the participants of the present workshop express interest in the proposal. ICRISAT conceives its role as an active partner of the network not only to help other *Arachis* genetic resources programs but also to benefit from the experience of other partners. IBPGR, in the framework of its program for crop networks, is keen to play a catalytic role in the establishment of this network. However, it does not foresee being an active participant as the network develops.

We see membership of the network not as a substitute for the policy of individual national program or of ICRISAT, but as a minimum basis for collaborative work on groundnut genetic resources. Such an effort will benefit all the members of the network and avoid duplication of effort. The agreement on a plan of action with well-defined priorities and commitments from all partners will also allow us to seek the additional funding that is necessary to achieve the objectives.

Objectives and Scope

To achieve uniformity and universalization of results, the following approaches are important.

Future collecting needs

Participants in networks could identify future needs, in addition to those given in Table 5 for ICRISAT, to enable them to decide priorities and share material collected, as in the workshop of *Arachis* workers held in 1989 (IBPGR 1990).

Characterization and documentation

Development of a common descriptor language and database is imperative. This will need:

- Development of an inventory of existing accessions. It is essential to provide access to the germplasm to all participants as is now the standard practice at ICRISAT. The production of comprehensive inventories requires an institute to compile and standardize data. For wild *Arachis* species, North Carolina State University, USA, is preparing an inventory in accordance with the recommendation of the Centro Internacional de Agricultura Tropical (CIAT) meeting on wild *Arachis* species.
- Development of common descriptors and compatible format. IBPGR and ICRISAT (1981) developed groundnut descriptors that are being revised. Efforts to produce descriptors for the wild *Arachis* species are in progress. They will result in developing a format to be used for exchange of information.
- An international database. Consequent sharing of results will require more than passport data in a central database. The database would include gene bank management data, characterization, preliminary evaluation data, and further evaluation data.
- Exchange of information. A crop network will facilitate a dynamic collaborative approach to making the data available in a form that will be useful to all the participants. One example is a computerized bibliography of crop genetic resource publications, listing reference material and updating research results. Further analysis of data will allow implementation of really collaborative efforts and sharing of work for better characterization and evaluation of *Arachis* germplasm.

Integrated conservation approach

A coordinated approach for conservation of genetic resources would need:

- Rationalization of collection. A database will provide information on redundancy of existing collections at different centers. This will help in rationalizing collection to avoid obvious duplications and sharing responsibilities in maintenance of accessions by participants.
- Safety duplication. The reduction in redundancy is important, but storage of each original accession in two separate long-term storage facilities is required to minimize the risk of loss of original germplasm.
- An integrated approach. Maintenance of a world collection should include studies on the influence of various techniques on viability and longevity of the germplasm conserved. The conservation methods may consist of cold storage of seeds, in-vitro conservation of vegetatively propagated wild *Arachis* species, and in-situ conservation of germplasm in their natural ecosystem. Networking can help to determine the appropriate approach.

Use of collection

To promote and improve utilization of germplasm by the international community, it is necessary make the collection more accessible through:

- Plant quarantine. With increasing exchange of germplasm an international network will help to facilitate meeting plant quarantine requirements of the participating countries. The support or strengthening of quarantine centers will be one of the responsibilities of the network. In the final analysis, however, plant quarantine is under national government responsibility and control.
- Characterization and evaluation. The registration of available evaluation data in the central database will increase the availability of evaluation information which in turn will enhance the use of germplasm.
- Enhancement. For better use of germplasm it is essential to transfer the desirable traits to good agronomic background, particularly when traits are transferred from wild *Arachis* species. Crop networking will not only have potential to stimulate collaborative activities for the enhancement of germplasm, but also will help smaller programs within the network to benefit from activities provided by larger institutions.
- Research. There is a need for additional research on proper maintenance conditions, use of collections, quality and quantity of genetic diversity available, incompatibility, etc. It will be very difficult for a single organization to undertake the research that is needed for groundnut germplasm. A collaborative approach within the network will

help to identify the research priorities and the appropriate organization to produce information useful to all the participants.

Development and Organization of the Network

Development and organization of the network will involve the following components:

- Inaugural workshop. An inaugural workshop will be organized, involving curators, breeders, and researchers working on *Arachis* will help to stimulate and establish a groundnut germplasm network.
- Basic principle. An agreement on free exchange of genetic resources and information should be required for membership of the network.
- Minimum action program. The participants should decide on priority of objectives, activities, and commitments for various participants.
- International database. The existing international database at ICRISAT will be further developed to strengthen the networking.
- Coordinating body. Election/nomination of a coordinating committee at the end of the workshop will be essential to support and execute the network activities. This will be subject to study and approval by participating organizations.
- Funding. Additional funding on clear and focused international programs of the network will be needed.
- Role of the IARCs and IBPGR. This will be discussed within the framework for participation of global responsibilities in agricultural research.

References

Amin, P.W., Singh, K.N., Dwivedi, S.L., and **Rao, V.R.** 1985. Sources of resistance to jassid (*Empoasca kerri* Pruthi), thrips [*Frankeniella schultzei* (Trybom)] and termites (*Odontotermes* sp.) in groundnut (*Arachis hypogaea* L.). Peanut Science 12:58-60.

Estes, J.W., and **Rao, V.R.** 1989. Computerized documentation and retrieval systems for genetic resources work at ICRISAT – present and future. Pages 71-74 *in* Collaboration in genetic resources: summary proceedings of a Workshop on Germplasm Exploration and Evaluation in India, 14-15 Nov 1988, ICRISAT Center, India. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Hawkes, J.G. 1981. Germplasm collection, preservation and use. Pages 57-83 *in* Plant Breeding II (Frey, K.J., ed.). Ames, Iowa, USA: Iowa State University Press.

IBPGR (International Board for Plant Genetic Resources). 1990. International Crop Network Series 2. Report of a Workshop on the Genetic Resources of Wild *Arachis* Species, 29 Feb-2 Mar 1989, Cali, Colombia, including the preliminary descriptors for *Arachis* (IBPGR/ICRISAT). Rome, Italy: IBPGR.

IBPGR/ICRISAT (International Board for Plant Genetic Resources/ International Crops Research Institute for the Semi-Arid Tropics). 1981. Groundnut descriptors (revised). Rome, Italy: IBPGR. 23 pp.

ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1989. Summary proceedings of the Second Coordinators' Meeting on Peanut Stripe Virus, 1-4 Aug 1989, ICRISAT Center, India. Patancheru, A.P. 502 324, India: ICRISAT.

Mehan, V.K. 1989. Screening groundnuts for resistance to seed invasion by *Aspergillus flavus* and to aflatoxin production. Pages 323-334 *in* Aflatoxin contamination of groundnut: proceedings of the International Workshop, 6-9 Oct 1987, ICRISAT Center, India. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Mengesha, M.H., Khanna, P.P., Chandel, K.P.S., and **Rao, N.K.** 1989. Conservation of world germplasm collections of ICRISAT mandate crops. Pages 65-69 *in* Collaboration on genetic resources: summary proceedings of a Workshop on Germplasm Exploration and Evaluation in India, 14-15 Nov 1988, ICRISAT Center, India. Patancheru, A.P. 502 324, India: International Crops Research for the Semi-Arid Tropics.

Rao, V.R. 1980. Groundnut genetic resources at ICRISAT. Pages 47-57 *in* Proceedings of the International Workshop on Groundnuts, 13-17 Oct 1980, ICRISAT Center, India. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Resslar, P.M. 1980. A review of nomenclature of the genus *Arachis* L. Euphytica 29:813-817.

Singh, A.K. 1988. Putative genome donors of *Arachis hypogaea* (*Fabaceae*), evidence from crosses with synthetic amphidiploids. Plant Systematics and Evolution 160:143-151.

Smartt, J., Gregory, W.C., and **Gregory, M.P.** 1978. The genomes of *Arachis hypogaea*. I. Cytogenetic studies of putative genome donors. Euphytica 27:665-675.

Subrahmanyam, P., McDonald, D., Reddy, L.J., Nigam, S.N., Moss, J.P., Singh A.K., and **Rao, V.R.** 1990. Resistance to rust and late leaf spot of groundnut at ICRISAT Center: problems and progress. Pages 85-91 *in* Proceedings of the Fourth Regional Groundnut Workshop for Southern Africa, 19-23 Mar 1990, Arusha, Tanzania. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Thomas, T.A., Rao, K.E.P., and **Pundir, R.P.S.** 1989. ICRISAT/NBPGR joint evaluation of germplasm in India. Pages 59-64 *in* Collaboration on genetic resources: summary proceedings of a Workshop on Germplasm Exploration and Evaluation in India, 14-15 Nov 1988, ICRISAT Center, India. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Valls, J.F.M., Rao, V.R., Simpson, C.E., and **Krapovickas, A.** 1985. Current status of collection and conservation of South American groundnut germplasm with emphasis on wild species of *Arachis*. Pages 15-33 *in* Proceedings of an International Workshop on Cytogenetics of *Arachis*, 31 Oct-2 Nov 1983, ICRISAT Center, India. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

IBPGR and Groundnut Genetic Resources

V. Ramanatha Rao[1]

Abstract

*Recognition of the need for fostering work on plant genetic resources by the international community led to the formation of the International Board for Plant Genetic Resources (IBPGR). IBPGR has been promoting scientific efforts in relation to various germplasm, including that of groundnut (*Arachis hypogaea*), some which are briefly described here.*

Through IBPGR-sponsored groundnut germplasm collecting missions, a total of 2679 (both cultivated and wild Arachis *species) samples have been collected, which have been distributed widely. IBPGR has supported the establishment of a field gene bank of wild* Arachis *species at the Centro Nacional de Recursos Geneticos (CENARGEN), Brasilia, Brazil.*

For germplasm characterization, evaluation, and documentation, IBPGR has actively supported and/or encouraged some projects on groundnut. It published the groundnut descriptors jointly with ICRISAT in 1981. A revision of this list and a separate one for wild Arachis *species are in preparation. There have been 71 IBPGR alumni from 12 different countries working in 24 gene banks that hold groundnut germplasm. It has sponsored meetings of various committees that have significantly influenced the work on groundnut germplasm. IBPGR hopes that a groundnut genetic resources network will be established that would help in ensuring better conservation and wider use of collections, provide better support to groundnut programs, and involve the developing countries more closely in genetic resources activities, with the cooperation of all concerned.*

Résumé

L'IBPGR et les ressources génétiques arachidières: *Reconnaissant le besoin de promouvoir des recherches sur les ressources génétiques des plantes par la communauté internationale, le Conseil international des ressources phytogénétiques (IBPGR) s'est constitué. L'IBPGR a soutenu des efforts scientifiques pour diverses activités sur les ressources phytogénétiques, y compris celles de l'arachide (*Arachis hypogaea*), dont certaines sont brièvement décrites dans cette communication.*

*Au cours des missions de collecte des ressources phytogénétiques d'arachide organisées par l'IBPGR, on a collecté au total 2679 échantillons d'arachide (espèces cultivées et sauvages d'*Arachis*), qui ont été distribués largement. L'IBPGR a appuyé la création d'une banque de gènes sur le terrain pour des espèces sauvages d'*Arachis *au Centro nacional de recursos geneticos (CENARGEN), à Brasilia, au Brésil.*

*Pour la caractérisation, l'évaluation et la documentation des ressources génétiques l'IBPGR a appuyé activement et/ou encouragé certains projets relatifs à l'arachide. Il a publié les descripteurs d'arachide conjointement avec l'ICRISAT en 1981. Une révision de cette liste et une liste séparée pour les espèces sauvages d'*Arachis *sont en préparation. Il y a eu 71 chercheurs formés à l'IBPGR provenant de 12 pays différents oeuvrant dans 24 banques de gènes qui conservent des ressources génétiques d'arachide. Il a parrainé des réunions de divers comités qui ont influencé de manière marquée le travail sur les ressources génétiques d'arachide. L'IBPGR espère qu'un réseau de ressources génétiques de l'arachide sera établi, car cela permettra d'assurer une meilleure conservation et un usage plus étendu des collections, d'appuyer mieux les programmes arachidiers et de mettre plus étroitement en jeu les pays en développement pour les activités sur les ressources génétiques, avec la coopération de tous les intéressés.*

1. Genetic Diversity Officer, International Board for Plant Genetic Resources IBPGR), Food and Agriculture Organization of the United Nations (FAO), via delle Sette Chiese 142, 00145 Rome, Italy.

Ramanatha Rao, V. 1992. IBPGR and groundnut genetic resources. Pages 311–315 *in* Groundnut – a global perspective: proceedings of an international workshop, 25–29 Nov 1991, ICRISAT Center, India (Nigam, S.N., ed.). Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

The threat of genetic erosion and the need for conservation of plant genetic resources was recognized by a few perceptive scientists as early as the 1940s. However, the urgency of the action was really felt in the 1960s and resultant international interest led to the formation of the International Board for Plant Genetic Resources (IBPGR) as a component of the Consultative Group on International Agricultural Research (CGIAR). The main objective of IBPGR is to foster "the study, collection, preservation, documentation, and evaluation, and utilization of genetic diversity of useful plants for the benefit of people throughout the world". IBPGR has been charged to act as a "catalyst both within and outside the CGIAR system in stimulating the action needed to sustain a viable international program for the conservation of genetic resources of these plants". IBPGR, which started with a small Secretariat housed and supported by the Food and Agriculture Organization of the United Nations (FAO), has grown into a CGIAR Institute in its own right and will shortly begin operating as an institute administratively independent from FAO under the name of the International Plant Genetic Resources Institute (IPGRI).

Since its formation, IBPGR has been playing a leading role in catalyzing and promoting scientific efforts in genetic resources activities, in collaboration with various national, regional, and international programs, including the other International Agricultural Research Centers (IARCs). In this context, IBPGR undertook several activities in the area of groundnut (*Arachis hypogaea*) and its related wild *Arachis* species germplasm, some of which are briefly described below. It is necessary to make it clear first that

Table 1. Countries, dates, and number of accessions of cultivated groundnut collected through IBPGR-sponsored missions.

Country	Date	Accessions	Country	Dates	Accessions
Algeria	Oct 1984	2	Mauritius	Mar 1985	3
Argentina	Mar–Jun 1977	12	Mexico	Jun–Dec 1983	3
	Apr–May 1983	4		Oct–Nov 1985	1
Bolivia	Apr 1977–Oct 1981	278		May–Oct 1986	2
	Apr–May 1983	51	Mozambique	Apr–May 1981	113
Botswana	Apr 1985	8	Nepal	Oct–Nov 1985	11
Brazil	Jun–Sep 1981	30	Paraguay	Jun 1977	8
	Mar–May 1982	27	Peru	Jan–Mar 1980	148
	Mar–May 1983	16		Mar 1982	2
	Mar–Jun 1985	28	Sierra Leone	Nov–Dec 1977	12
	Apr 1986	81	Somalia	Aug–Sep 1979	5
	Apr–May 1987	7	Sri Lanka	Sep 1986–Jun 1987	4
Burkina Faso	Oct 1981	1	Sudan	Sep–Oct 1980	27
Cameroon	Oct–Dec 1979	27		Oct 1982–Mar 1985	4
Chad	Oct–Dec 1987	2	Syria	Jul–Aug 1985	4
Ecuador	May 1980	53	Tanzania	Jul–Aug 1981	27
Egypt	Oct 1981	14	Thailand	Jan 1978–Dec 1980	28
	Oct 1982	3	Yemen	May–Jun 1980	2
Ethiopia	Feb–Mar 1981	1	Togo	Dec 1983–Mar 1984	27
Ghana	Nov 1982–Feb 1983	40	Uruguay	1984–1985	248
Guinea	Oct–Dec 1989	148	Venezuela	Sep–Nov 1987	1
India	Oct–Nov 1982	8	Zambia	Jun 1980	82
	Sep 1984–Jan 1985	2		Apr–Jun 1981	114
Kenya	Jul 1988	9		Jun–Jul 1982	37
Laos	Nov 1983	23		Jun 1984	10
Malagasy			Zaire	Aug–Oct 1987	39
Republic	May–Jun 1984	3	Zimbabwe	Apr–Jul 1982	183
	1990	24		Mar–Aug 1985	78
Malawi	Mar–Apr 1979	33			
Mali	Jan–Feb 1982	9	Total		2167

IBPGR is not a 'donor' agency. It is an international scientific organization that seeks collaboration with other scientific institutions to fulfil its mandate. In doing so, IBPGR sometimes gives financial support to work at the collaborating institute.

Germplasm Collecting

Over the years IBPGR has made considerable efforts to rescue germplasm threatened by genetic erosion and to fill gaps in the existing collections so that they become more representative. These efforts involved germplasm collecting and facilitating the distribution of the material collected. IBPGR has supported a number of groundnut germplasm collecting missions (both cultivated and wild *Arachis* species) and 2679 samples have been collected. A significant number of these missions has been targeted at collecting groundnut germplasm, while others were multi-crop missions. The numbers of groundnut accessions collected are given in Table 1 and those of wild species in Table 2. Some joint projects, such as the one for *Arachis* species in Brazil, are continuing.

As part of its efforts to facilitate distribution of germplasm, IBPGR has supported the multiplication of South American *Arachis* germplasm at Texas A&M University, Stephenville, Texas, USA, for the express purpose of despatching the seed to ICRISAT. This was necessary since ICRISAT could not import groundnut seed directly from South America due to quarantine regulations. Seed of all groundnut germplasm samples collected by IBPGR without the direct participation of ICRISAT is also sent to ICRISAT through IBPGR's Seed Handling Units. IBPGR has also supported the establishment of a field gene bank of wild *Arachis* species at the Centro Nacional de Recursos Geneticos (CENARGEN), Brasilia, Brazil.

Table 2. Countries, dates, and number of wild *Arachis* species accessions collected through IBPGR-sponsored missions.

Country	Dates	Accessions
Argentina	Dec 1976	1
	Mar–Apr 1977	2
	Mar–May 1980	2
	Mar–May 1982	10
Bolivia	Apr 1980	8
	May 1983	63
Brazil	Dec 1976	14
	Jun–Sep 1981	25
	Mar–May 1982	41
	Mar–May 1983	44
	Apr 1984	30
	Aug 1984	52
	Mar–Jun 1985	97
	Apr 1986	50
	Apr–May 1987	41
Paraguay	Jun 1977–Apr 1978	20
Uruguay	Oct 1978–Mar 1981	2
	1984–85	10
Total		512

Germplasm Characterization and Evaluation

The characterization and evaluation of conserved germplasm, although essential to the utilization of the material, have never really kept pace with collecting and conservation activities. IBPGR has actively supported and/or encouraged the growing out of material and recording of characterization and evaluation data on the samples. However such activities have mostly been limited to crops that are not within the mandates of other CGIAR centers. A few studies on genetic variability in groundnut germplasm, using morpho-agronomic traits, were supported in the past (Table 3). For example, the material collected in Thailand during 1980 was characterized by the Department of Botany, Kasetsart University in 1981–82. Similarly the groundnut germplasm collected during 1977–1982 from South America was evaluated at the Stephenville campus of Texas A&M University using the minimum descriptors, while being grown out for duplication at ICRISAT. This work at the Texas Agricultural Experiment Station (TAES) resulted in the publication of a catalog (Simpson et al. 1986). The 248 samples collected in Uruguay in 1984 were characterized during 1984–85 at the Universidad de la Republica, Montevideo. However, IBPGR believes that evaluations are highly environment specific and that this work is better undertaken by the crop improvement programs concerned.

Documentation

IBPGR's efforts in groundnut germplasm documentation are presented in Table 4. One of the IBPGR's earliest efforts was to support the establishment of the International *Arachis* Information Service for Germplasm Resources at the University of Florida, USA, during 1976–77. The *International Peanut Program*

Table 3. IBPGR–supported groundnut characterization and evaluation projects.

Institute	Dates	Type of material	Accessions
Department of Botany, Kasetsart University, Thailand	1981–82	Local landraces	28
Texas A&M University, Stephenville, USA	1982	South American landraces collected in 1976–1982	681
Instituto Nacional de Tecnologia Agropecuaria, Manfredi, Argentina	1983–84	Wild & cultivated groundnut	280
Plant Genetic Resources Program, Direction de la Recherche Agronomique, Cacaveli, Togo	1984–85	Local landraces	15
Universidad de la Republica, Montevideo, Uruguay	1984–85	Local landraces	248
Sri Lanka	1983–84	Local landraces	24

Table 4. IBPGR–sponsored groundnut documentation projects.

Organization	Dates	Title of the project
University of Florida, USA	1976–77	International *Arachis* Information Service for Germplasm Resources
		Global Data Base for *Arachis* germplasm
Texas A&M University, Stephenville, USA	1983	Catalog of the *Arachis* material collected in the period 1976–1983
	1985	Catalog of minimum descriptors of groundnut germplasm collections from South America, 1977–1982 (681 accessions)

Newsletter and two volumes of inventories for five collections were issued under this joint program.

Meaningful documentation of genetic resources is essential for studying the variation present and for accessing germplasm for crop improvement. Since its inception, IBPGR has supported the preparation and publication of internationally agreed descriptor lists for crops. IBPGR co-sponsored the IBPGR/ICRISAT ad hoc Working Group on Groundnut Germplasm, and following the recommendations of this committee, the first list for groundnut was published jointly in 1981 (IBPGR/ICRISAT 1981). This list is presently under revision in collaboration with ICRISAT and will be printed early in 1992. At the initiative of ICRISAT and following the recommendation of a Workshop on the Genetic Resources of Wild *Arachis* Species [held at the Centro Internacional de Agricultura Tropical (CIAT), Cali, Colombia, 29 Feb-2 Mar 1989], a preliminary list of descriptors of *Arachis* was produced as part of the report of the Workshop (IBPGR 1990). IBPGR hopes that these descriptors will be used universally to characterize and evaluate *Arachis* germplasm, thus simplifying the process of exchanging and analyzing data from various sources.

Training

IBPGR has not conducted any specific training programs on the genetic resources activities of groundnut. However, several of the staff working in various national gene banks that conserve groundnut germplasm, have benefitted from attending IBPGR-sponsored training programs. In the past 10 years, there have been 71 IBPGR alumni (at various levels of expertise) from 12 different countries working in 24 gene banks that hold groundnut germplasm. If the idea of an international groundnut genetic resources network becomes operational, priorities for training could be identified and action could be taken as required.

Meetings and Workshops

Since its inception IBPGR has worked on various crop species following recommendations made by

Crop Advisory Committees. Such a committee was never established for groundnut. However, it established an ad hoc Working Group in 1979. The meeting of this group was sponsored jointly with ICRISAT in September 1979 at ICRISAT Center, India. A number of decisions made at this meeting, such as the ones on the priority areas for collection of *Arachis* species, and development of groundnut descriptors, influenced the course of *Arachis* genetic resources work. IBPGR also supported the convening of the subcommittee on descriptors in Richmond, Virginia, USA, in 1980 that resulted in the finalization of groundnut descriptors, which was published in 1981 (IBPGR/ICRISAT 1981).

IBPGR also convened a group of scientists for a workshop on the genetic resources of wild *Arachis* species at CIAT, Cali, Colombia in 1989. This workshop was aimed at developing a collaborative program on wild species of groundnut. A number of topics such as the possible development of an *Arachis* network, the use of wild species in groundnut improvement, the taxonomic problems in the genus, further collecting requirements, and descriptors for wild species were discussed. A report of the workshop, containing the recommendations and the preliminary list of descriptors for wild *Arachis*, has been published (IBPGR 1990), as mentioned previously.

Crop Genetic Resources Network

IBPGR feels that crop genetic resources networks would help in ensuring wider use of germplasm collections, provide better support to crop improvement programs, and involve the developing countries more closely in plant genetic resources activities. Such a network for groundnut germplasm is conceived as a partnership in learning and problem solving. Its activities will be based on exchange of information on methods and results, scientific consultation in planning, sharing of material and data, defined commitments for all partners of the network, and on the acceptance of special duties/responsibilities by partners in the best position to provide services to the benefit of all members of the network. The network will be operating in the framework of policies that govern each participating country or organization. IBPGR has been looking for some time to foster such an activity for groundnut genetic resources and it was briefly discussed at a meeting of *Arachis* workers in 1989, convened by IBPGR. Participants of that meeting recommended strongly that a network be established to include all *Arachis* germplasm (IBPGR 1990). We are looking forward to the collaboration of ICRISAT and other interested national programs to develop such a network.

References

IBPGR (International Board for Plant Genetic Resources). 1990. International Crop Network Series. 2. Report of a Workshop on the Genetic Resources of Wild *Arachis* Species, 29 Feb-2 Mar 1989, Cali, Colombia, including the preliminary descriptors for *Arachis* (IBPGR/ICRISAT). Rome, Italy: IBPGR.

IBPGR/ICRISAT (International Board for Plant Genetic Resources/ International Crops Research Institute for the Semi-Arid Tropics). 1981. Groundnut descriptors (revised). Rome, Italy: IBPGR.

Simpson, C.E., Howard, E.R., Higgins, E.L., and **Thomas, G.D.** 1986. Catalog of minimum descriptors of *Arachis hypogaea* L. Germplasm collections from South America, 1977–1982. Bulletin, Texas Agricultural Experiment Station no. MP-1599. 39 pp.

Biotechnology for Improvement of Groundnut (*Arachis hypogaea*)

A.K. Weissinger[1]

Abstract

*Biotechnology, especially technologies for genetic analysis and gene transfer, is likely to make a significant contribution to groundnut (*Arachis hypogaea*) improvement in the future. Molecular marker technologies are increasing in resolution and declining in cost. Two of the most advanced of these technologies, restriction fragmemt length polymorphism (RFLP) and randomly amplified polymorphic DNA (RAPD), have been successfully applied to both the cultivated groundnut and its wild relatives. Current results show that the cultivated materials are highly homogeneous, while the diploid species form a reservoir of diverse germplasm. Molecular marker technologies are sufficiently advanced to allow development of genetic maps of both groundnut and of the diploid species. Molecular technologies can also contribute greatly to introgressive gene transfer schemes by allowing alien genes to be followed in backcross progenies, and by allowing the detection of more than one gene contributing to a single phenotype.*

Transformation technology is also expanding rapidly. Its application in groundnut is at a relatively primitive level, but is promising. Tissue culture technology is well developed for the cultivated species. Transient expression and stable transformation of groundnut tissues by microprojectile bombardment have been demonstrated. This work demonstrates the efficacy of micro-projectile bombardment, a method for choosing recipient explants, and the utility of kanamycin selection of transgenic tissues. Finally, transient expression has been demonstrated in embryonic axes and in embryogenic calli, both of which are highly regenerable materials.

Résumé

Biotechnologie d'amélioration de l'arachide *(***Arachis hypogaea***) : La biotechnologie, spécialement les technologies pour l'analyse génétique et le transfert de gènes, est appelée à contribuer utilement à l'amélioration de l'arachide (*Arachis hypogaea *L.) à l'avenir. Les technologies de marqueurs moléculaires deviennent de plus en plus précises et moins coûteuses. Deux de ces technologies les plus avancées: l'analyse RLFP et l'amplification à monodéterminants (RAPT) ont été appliquées avec succès à l'arachide cultivée et également à ses parents sauvages. Les résultats courants montrent que les matériels cultivés sont extrêmement homogènes, tandis que les espèces diploïdes forment un réservoir de diverses ressources génétiques. Les technologies des marqueurs moléculaires sont assez poussées pour permettre de perfectionner des cartes génétiques de l'arachide aussi bien que des espèces diploïdes. Les technologies moléculaires peuvent également contribuer largement à des projets de transferts de gènes par introversion en permettant à des gènes étrangers d'être suivis dans les descendances à rétrocroisement et en permettant le dépistage de plus d'un gène qui contribue à un simple phénotype.*

La technologie de la transformation s'étend aussi rapidement. L'application dans le cas de l'arachide est à un niveau relativement rudimentaire mais promettant. La technologie de la culture de tissus est bien développée pour les espèces cultivées. On a démontré l'expression transitoire et la transformation stable de tissus d'arachide par bombardements de micro projectiles. Ce travail démontre une efficacité du bombardement à micro projectiles, méthode pour choisir les explants récipiendaires et l'utilité de la sélection de kanamycine de tissus transgéniques. Finalement, l'expression transitoire a été démontrée dans des axes embryonnaires et des calli embryonnaires qui sont des matériels hautement régénérables.

---

1. Assistant Professor of Crop Science and Biotechnology, Department of Crop Science, P.O. Box 7620, North Carolina State University, Raleigh, NC 27695-7620, USA.

Weissinger, A.K. 1992. Biotechnology for improvement of groundnut (*Arachis hypogaea*). Pages 317–328 *in* Groundnut – a global perspective: proceedings of an international workshop, 25–29 Nov 1991, ICRISAT Center, India (Nigam, S.N., ed.). Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

The past decade has seen the emergence of an array of new technologies for plant improvement involving tissue culture and direct manipulation of DNA. Some of these will be of fundamental importance because they allow identification and manipulation of genetic variation of crop species with a degree of precision unattainable with more conventional technologies. Such technologies are of special interest for use in groundnut (*Arachis hypogaea*) breeding, because they could greatly facilitate efforts to increase the limited genetic diversity of germplasm sources from which commercial varieties are derived. Although many areas of biotechnology are potentially useful for groundnut improvement, two technologies are likely to be applied in the immediate future. These are molecular marker technology, and plant gene transfer (transformation).

Molecular marker technology, such as restriction fragment length polymorphism (RFLP) analysis and randomly amplified polymorphic DNA (RAPD) by the polymerase chain reaction (PCR), provide methods by which important linkage groups can be identified and mapped within the genome. Once these linkages are identified, their presence or allelic condition can be correlated with phenotypic effects. Information of this kind is especially important for identifying linkages which contribute to quantitative traits, and for identifying useful linkage groups in wild relatives that could be transferred to the cultivated species. Molecular marker technology is also potentially useful for identifying and cloning genes that could subsequently be inserted into adapted varieties through transformation.

Transformation is potentially of great utility for the incorporation of alien genes into groundnut gene pools. Transformation systems incorporate elements from many disciplines, including molecular biology, recombinant DNA technology, tissue culture, the biology of host-pathogen interaction, and physical science. While there are currently no published protocols for transformation of groundnut, the required technology is developing rapidly.

Molecular Markers

DNA-based molecular marker technology permits rapid, high-resolution characterization of genetic variants. Because they are based on structural analysis of DNA, rather than proteins or other gene products, these technologies are unaffected by environment, developmental stage, or physiological condition of the source plants. Further, they are not affected by dominance relationships among alleles, which can complicate observation of whole-plant traits.

Limited classification and genetic analysis of *Arachis* species has been attempted on the basis of various types of bulk DNA characterization. Atreya et al. (1985) analyzed DNA buoyant density, melting temperature (Tm), and base composition of five species of the genus *Arachis*. Buoyant densities were found to be relatively invariant except for that of *A. villosulicarpa*. Guanine and cytosine (GC) content was heterogeneous among the species tested, suggesting that GC content is species-specific. DNA melting curves also contained species-specific components. Buoyant densities differed from values predicted from Tms, indicating the presence of rare or modified bases. The findings in this study supported the classification of Gregory and Gregory (1979).

Atreya and Subrahmanyam (1989) compared five species of the genus *Arachis* by analysis of repetitive DNA. Highly repeated DNA varied widely, with diploid species having approximately twice as much as the tetraploid species. The diploid species, *A. regonii* and *A. villosulicarpa*, differed significantly from one another, while the tetraploid species, *A. hypogaea*, *A. glabrata*, and *A. hagenbeckii*, had similar amounts of highly repeated DNA. The authors suggested that highly repeated DNA elements have diminished in the tetraploid members during speciation. This may have affected the intersectional crossabilities observed in the genus. Generally, repetitive DNA analysis supported classifications based on other criteria.

Resslar et al. (1981) estimated 2C amounts of DNA by cytophotometry for 12 taxa of section *Arachis*. This study detected a significant amount of diversity. Significant differences were detected between the diploid series *Annuae* and *Perennes*, although no differences were detected between taxa within these series. Within the tetraploid series *Amphiploides*, differences were detected between *A. monticola* and *A. hypogaea*. Two subspecies of *A. hypogaea*, subsp *hypogaea* and subsp *fastigiata* were found to differ significantly. These data were found to support classifications based on other criteria (Gregory et al. 1973), and supported the notion that chromosomal variation has played a relatively small part in the evolution of the section *Arachis*.

While these techniques have provided useful taxonomic information, their utility in the context of groundnut improvement is very limited. Bulk DNA analyses can help to differentiate between major taxa, but they cannot provide the level of resolution required for genomic mapping, monitoring breeding populations for the presence of specific quantitative trait loci, or other more sophisticated applications. Structural analysis of DNA, such as restriction fragment analysis or PCR-based amplification of internal sequences, is required for these purposes.

Restriction fragment length polymorphism (RFLP)

RFLP analysis is based upon the fact that genetically distinct organisms differ from one another in the content and sequence of nucleotide bases in their genomic DNA. Restriction enzyme recognition sequences therefore occur at different frequencies and in different locations within the DNA of each genetic variant. Digestion of the genomic DNA from plants with different genotypes will result in the production of different numbers and sizes of restriction fragments. Theoretically, this process can discriminate between even very similar genomes, although highly related genomes may produce visibly distinct restriction fragment patterns with some restriction enzymes but appear identical when analyzed with others.

Because genomes of higher plants are complex, cleavage with restriction enzymes typically results in the production of very large numbers of fragments of diverse sizes. These fragments can be separated according to length by agarose gel electrophoresis, but this procedure is inadequate to resolve all fragments as discrete bands on a gel. Instead, DNA fragments in the gel are transferred to support membranes, which are then hybridized to labeled (most commonly ^{32}P) DNA probes. Probe sequences are derived either from known genes or unknown, low-copy-number genomic sequences cloned from the same or a related species. Autoradiography of the blot produces an image of the hybridizing fragments.

This process simultaneously simplifies and enhances the power of the analysis. Since only a very small number of restriction fragments will hybridize with any single-copy probe sequence, the pattern of hybridizing bands is far simpler than the pattern produced when all fragments are visible on the stained gel prior to transfer. Further, since each probe sequence will hybridize to a different set of fragments, restriction fragment arrays from two genotypes that appear identical when probed with one sequence may well produce distinct patterns when probed with another. Thus, by altering both restriction enzyme and probe combinations, distinct banding patterns can be obtained from most genotypes. In its simplest form, RFLP technology can be a very powerful taxonomic tool.

Hybridizing bands also function as genetic markers. Genetic mapping and analysis with these markers is essentially the same as that using phenotypic markers, except that it is unperturbed by environmental factors. Also, RFLP markers behave as codominant alleles. Thus, a genetic map can be constructed on which the relative positions of markers can be established. Markers can also be assigned to linkage groups (i.e., to specific chromosomes). Finally, it is possible to establish correlations between the presence of a particular molecular marker (hybridizing restriction fragment) and a phenotypic trait. This is especially useful for the identification of quantitative trait loci (QTL), chromosomal segments which contribute to the expression of complex traits.

Very little published information is available regarding application of RFLP technology to groundnut. Kochert et al. (1991) studied RFLP variability in eight U.S. groundnut varieties, including two cultivars from each of the four market types. They also examined 14 wild species accessions of *Arachis*. DNA from each accession was subjected to digestion with each of eight restriction enzymes (i.e., eight separate digestions were carried out for each accession).

Probes used in the study were random genomic clones, generated by *Pst* I digestion of DNA from cultivated groundnut. This enzyme was chosen for production of probes because it had been shown previously to select for low-copy sequences. Clones were screened against groundnut genomic DNA blots to select only those clones representing low-copy sequences. Probes which hybridized to blots of chloroplast DNA were eliminated. A total of 21 randomly chosen clones were screened, and 7 were identified which were useful in detecting polymorphism.

RFLP variation was found to be low among the allotetraploids, which included the U.S. cultivars and *A. monticola*. The RFLP patterns of *A. monticola* were nearly identical to those of the cultivated species. RFLP patterns of the allotetraploids were typically more complex than those of the diploid accessions. The diploid species were far more variable than the allotetraploids. A dendrogram based on RFLP data from the species generally separated the accessions according to classifications based on other criteria, but produced groupings not previously reported.

Interestingly, RFLP patterns characteristic of tetraploid cultivars could in some instances be reconstructed by combining the patterns produced by particular diploid accessions. This result suggests that the diploids thus identified could be the progenitors of the tetraploid species, although the authors felt that these results were somewhat ambiguous.

The authors concluded that RFLP data provide useful information for studying the phylogeny and taxonomy of the genus, but additional information is required regarding the variation within and among accessions across the range of a species. Lack of knowledge regarding the molecular basis for differences in banding patterns between accessions complicates the evaluation and use of these data. These results also suggest that construction of an RFLP map for the genus will require the use of an interspecific cross, because there is insufficient polymorphism within the cultivated species to permit construction of a map using currently available technology. This finding agrees with that of an earlier study by Halward et al. (1990), in which more diverse accessions of *A. hypogaea* were screened for RFLP variation.

Finally, Kochert et al. (1991) concluded that because the cultivated species is highly homogeneous, breeding programs will be dependent upon incorporation of wild materials for future gains in pest resistance and other traits. RFLP analysis is an appropriate method for the identification of variant materials for this purpose.

In more recent research, RFLP analysis was used to examine chloroplast DNA variation in the two subspecies of domesticated groundnut, tetraploid wild groundnut, and four diploid species of section *Arachis* (H.T. Stalker, North Carolina State University, personal communication). Independent DNA samples were digested with nine different restriction enzymes. Following electrophoresis and blotting, DNAs were probed with cloned chloroplast sequences from *Solanum tuberosum* and *Hordeum vulgare*. Only four of the nine enzymes used revealed restriction site differences among the species. Results indicated high genetic affinities between species of section *Arachis*. They also support the designation of *A. duranensis* as the maternal genomic donor of the cultivated species. Importantly, chloroplast DNA pattern data did not support an earlier proposal (Singh 1988) that *A. batizocoi* is the maternal genome donor.

RFLP analysis of cytoplasmic DNA is a very useful technology for taxonomic investigations because its strict maternal inheritance in some species permits the elucidation of maternal lineage. The utility of such analysis to the plant improvement process is limited, however. It is primarily of interest for manipulation of traits that exhibit strict maternal inheritance. If a phenomenon is known to be associated with a particular cytoplasmic source, this procedure could allow it to be followed.

Randomly amplified polymorphic DNA (RAPD)

RAPD involves the use of PCR to amplify genomic sequences (Caestano Anolles et al. 1991; Williams et al. 1991). As in RFLP analysis, the technology is based upon the fact that genetically distinct individuals must differ from one another at the DNA level. In this procedure, a short (approximately 10 nucleotides) primer sequence of defined, but arbitrary, sequence is used as a PCR primer. Unlike conventional PCR procedures, only a single primer is used. The single primer sequence is fortuitously complementary to target sites upon opposite strands of the sequence to be amplified. If these target sites are close enough together to allow DNA synthesis along the whole distance between target sites, PCR results in the amplification of a DNA species with defined termini (complementary to the primer sequence, and in opposite orientations) and of a length equal to the distance between target sites. When the products obtained following single-primer amplification are separated electrophoretically and stained with ethidium bromide, a relatively simple band pattern is revealed. Like RFLP, this procedure produces a diagnostic pattern for each genotype/primer sequence combination. Differences in band patterns are indicative of molecular differences between genotypes, although related genotypes may produce identical amplification products with some primer sequences.

The power of RAPD analysis can be enhanced by digestion of amplification products with restriction enzymes following PCR. Enzymes having a four-nucleotide recognition sequence are often used in order to maximize the probability of cleavage within amplification products, and thus maximize resolution of the system.

The presence of specific amplification products is indicative of the presence of particular sequences in the genome from which they were derived, and therefore function as molecular markers for chromosomal segments. They can be used in a manner analogous to RFLP for taxonomic studies, construction of linkage maps, and as indicators of the presence and allelic condition of genetic loci, including QTL. Unlike RFLP markers, RAPD markers express the equivalent of dominance, in that a marker is considered dominant if it is amplified during PCR. It is not possible to distinguish between homozygous and heterozygous individuals using conventional PCR technology.

RAPD analysis has distinct advantages over RFLP. The procedure is typically faster because no transfer step (Southern transfer) is required. No radioactive materials are required. Primer sequences are produced synthetically and require no cloning operations. The cost of the Taq polymerase used in the PCR step is a concern, but this is likely to be overcome by reducing reaction volumes, and by the steadily declining cost of the enzyme in the market (R.R. Sederoff, North Carolina State University, personal communication).

A major constraint of RAPD analysis is that amplification conditions can vary, thus altering the amplification products generated during PCR of a DNA sample. Further, while it has become common for RFLP probes to be exchanged as a means of correlating maps produced by different laboratories, the primers used in RAPD analysis are more often generated on-site, and are peculiar to the laboratory that has generated them. Thus each data set is unique and cannot be correlated readily with those generated in other laboratories, or under different amplification conditions. These shortcomings will likely be overcome as the use of this procedure expands. It is likely that publication of primer sequences and reaction conditions, and data regarding the array of products generated during amplification will allow results to be compared between laboratories.

Halward et al. (1991a, 1992) examined DNA from a very diverse array of *Arachis* genotypes by single-primer amplification. These included 2 groundnut cultivars, 25 unadapted germplasm lines of *A. hypogaea*, *A. monticola*, *A. glabrata*, and 29 diploid wild *Arachis* species. In addition, 100 F_2 progeny from each of 2 interspecific crosses were evaluated for segregation of banding patterns. Amplifications were carried out with ten different arbitrary primer sequences, each ten nucleotides in length.

No polymorphism was detected among the cultivars with any of the primers. The wild species, however, were differentiated by most primers. Band sharing analysis produced dendrograms that were generally consistent with those generated using RFLP data. They also showed general agreement with the results of morphological analysis. F_2 banding patterns indicated genetic segregation, but were very complex. Homozygous and heterozygous individuals were indistinguishable under the specified conditions.

The authors concluded that single-primer amplification is a useful taxonomic tool, particularly when used in combination with data from other characteristics, such as morphology and isozyme patterns. The inability to differentiate among cultivated groundnut lines by this technique is in keeping with RFLP results (Kochert et al. 1991), and suggests that morphological variation among lines is due to only a small number of genes. This suggests that progress may be limited in breeding programs employing only adapted germplasm sources. Single-primer amplification may be of very limited utility for genetic mapping in groundnut. Although substantial variation can be obtained by proper choice of parents of mapping populations, patterns are complex and not well suited to mapping applications. The authors suggest that analysis of backcross populations, where progeny could be scored for presence or absence of a band, would be a more appropriate application of the technology.

In another study, Halward et al. (1991b) examined molecular marker variation in a broad-based collection of *Arachis* germplasm sources. These included 25 unadapted germplasm lines of *A. hypogaea*, representing all four botanical varieties, five of the six centers of diversity for groundnut, and introductions from Africa and China. Also included were 2 U.S. cultivars, *A. monticola*, and 29 accessions of diploid wild species.

Molecular polymorphism was assayed by three methods: 1) conventional RFLP analysis using cloned probes from groundnut and alfalfa (*Medicago sativa*); 2) arbitrary single-primer PCR amplification; and 3) conventional (two-primer) PCR amplification products digested with restriction endonucleases having tetra-nucleotide recognition sequences. Thirteen restriction enzymes were used for RFLP analysis. Single primer amplification was carried out with 10 primers, each 10 nucleotides in length. Standard PCR amplification of known sequences used pairs of defined primers, each 20 nucleotides in length. The sequence of three of these primers was taken from three genomic clones of groundnut. Degenerate primers were also made from conserved regions of the alcohol dehydrogenase (ADH) gene. Standard PCR products were also digested with four different restriction enzymes having tetra-nucleotide recognition sequences in an attempt to enhance resolution.

Results with all forms of molecular analysis indicated very little polymorphism among cultivated groundnuts, but abundant variation among diploid species. Although PCR-based analysis techniques offer potentially greater resolution, the most detailed analysis of the cultivated materials tested, PCR followed by restriction digest, revealed little variation. The authors suggest that the homogeneity among the botanical types of the cultivated groundnut may be the result of relatively recent speciation through polyploidy. The level of variation among wild species, compared to the low level of polymorphism among groundnut cultivars, suggests that wild species should be examined more intensely for sources of genetic variation in important traits.

Transformation

Plant transformation is the introduction and stable integration of alien genes into the genome of a recipient plant. With transformation, the gene pool available for improvement of a crop is essentially unlimited, and could include genes from virtually any organism. This technology could be especially useful for increasing the limited genetic variation available for the modification of certain traits in cultivated groundnut. As described below, it could also aid the transfer of useful genes from the diploid wild species into the allotetraploid cultivated species. At present, however, there does not appear to be any published protocol for the stable transformation of any *Arachis* species.

Elements of a transformation system for groundnut

All plant transformation systems, regardless of the species involved, have in common certain key elements. These include: 1) protocols for tissue culture, selection, and regeneration of plants; 2) an appropriate recipient tissue, either from cultured tissues or intact plants; 3) a selection scheme for recovery of transgenic tissues, including appropriate selectable marker genes; and 4) technology for introducing transforming DNA into recipient cells. Development of an efficient transformation protocol depends upon optimization of each of these elements.

In some species, the biology of the organism limits choices available for each of these essential components of the transformation system. For example, *Agrobacterium* does not readily infect most monocotyledonous species. Therefore *Agrobacterium* infection is not generally considered to be an ideal DNA transfer method for transformation of wheat (*Triticum aestivum*). Similarly, choices can be constrained by lack of pivotal technology, such as that required for regeneration of a particular explant, which prevent development of some otherwise promising gene transfer strategies.

Transformation protocols for groundnut are likely to be available in the near future. Development of the required technology has benefitted greatly from past work on groundnut, particularly the development of tissue culture protocols for the cultivated species.

Tissue culture, selection, and regeneration

Protocols for culture and regeneration of tissues into which transforming DNA has been delivered are an essential part of any transformation technology. This aspect of transformation has been one of the most problematical for many species. Fortunately, groundnut tissue culture is a well-established technology.

There are numerous reports in the literature of tissue culture and regeneration of groundnut from various explants (Bajaj 1984; Sastri et al. 1982). Certain of these protocols appear to be especially useful for development of groundnut transformation protocols. Sexually functional plants have been regenerated from immature embryos (Ozias-Akins 1989; Sellars et al. 1990), leaves of young seedlings (Bajaj et al. 1981; McKently et al. 1991; Mroginski et al. 1981; Pittman et al. 1983; Seitz et al. 1987), cotyledons (Bhatia et al. 1985; Illingworth 1968; McKently et al. 1990), and from embryonic axes (Atreya et al. 1984; Braverman 1975; Hazra et al. 1989). Regeneration can occur by primary organogenesis (McKently et al. 1991; Mroginski et al. 1981), i.e., by the development of shoots directly on the cultured explant, or by secondary organogenesis (Bajaj et al. 1981), the development of shoots from callus tissue. Regeneration through somatic embryogenesis has also been reported (Ozias-Akins 1989; Sellars et al. 1990) and may be one of the more promising procedures for use in transformation. While callus tissue has been recovered following protoplast release (Oelck et al. 1982), sexually functional groundnut plants do not appear to have been regenerated from protoplasts.

In the cultivated species, culture response appears to be strongly influenced by genotype (McKently et al. 1990; McKently et al. 1991; Mroginski et al. 1981; Seitz et al. 1987). Hormone content of culture media also is a critical factor (McKently et al. 1990; McKently et al. 1991; Mroginski et al. 1981). Developmental age of source explant also has a profound effect on performance of certain tissues, particularly leaflets from young seedlings (Mroginski et al. 1981).

As described below, transformation of the wild diploid species may be desirable, not for their improvement, but as an aid to gene isolation. This would necessitate development of culture and regeneration procedures for the recipient species. Several studies have addressed culture response of various species and interspecific hybrids (Stalker and Eweda 1988; Sukumar and Sree Rangasamy 1984). Generally, response in the diploid species appears to be adequate for incorporation into transformation procedures. Some, such as *A. villosulicarpa*, appear to exhibit extremely favorable regeneration characteristics (P. Ozias-Akins, University of Georgia, personal communication). Undoubtedly this substantial literature will facilitate efforts to transform wild relatives of the cultivated groundnut.

A suitable system for selection of transgenic tissues and plants is another important aspect of the transformation system. There is not yet any published information regarding the effects of antibiotics on groundnut tissues. Anecdotal evidence, however, suggests that antibiotics used in other plant species will also be applicable in groundnut. Hygromycin effectively limits growth of leaf tissue and embryogenic callus, and arrests growth of leaf-derived nonembryogenic callus at moderate levels (P. Ozias-Akins, University of Georgia, personal communication; A.K. Weissinger, unpublished data). Methotrexate also inhibits growth of nonembryogenic callus (A.K. Weissinger, unpublished data). Kanamycin is generally thought to be ineffective in groundnut tissues, and would thus permit an unacceptable level, of escapes if used in a transgenic selection system. It does not inhibit the growth of embryogenic callus (P. Ozias-Akins, University of Georgia, personal communication). Recently, however, Clemente et al. (1992) have shown kanamycin to be an effective selective agent when used to select stably transformed callus tissue growing on immature leaflets. It seems likely that the choice of antibiotic for transgenic selection may depend upon the explant tissue under selection. Choice of antibiotic and selective concentrations will probably have to be determined empirically for each explant and each groundnut genotype.

Regeneration procedures may affect the transgenic product in very specific ways, and therefore are seen primarily in terms of their efficiency and any lasting effects they may have on the performance of regenerated plants. When regeneration is examined as a part of a transformation system, however, its effects on the transformed product must also be considered.

DNA delivery technology

The choice of method for DNA delivery is crucial, because it in many ways defines the remainder of the transformation system. Several methods for DNA transfer are available for transformation of plants and could potentially be applied to groundnuts.

Agrobacterium-mediated transformation, by far the most broadly applied system currently in use, has not yet been reported for this species. However, wild-type *Agrobacterium* strains have been shown to infect groundnut and mediate gene transfer (Dong et al. 1990; Lacorte et al. 1991). Annecdotal evidence suggests that disarmed *Agrobacterium* strains can infect groundnut tissues, and there is evidence of at least transient transfer and expression of marker genes (S. Cooper-Bland, Scottish Crop Research Institute, personal communication). No transgenic plants or stably transformed tissues are reported to have been derived by treatment with disarmed *Agrobacterium* strains. Success in other recalcitrant species suggests, however, that *Agrobacterium*-mediated transformation of groundnut might be accomplished if the right combination of explant tissue and bacterial strain can be found.

Direct DNA uptake methods for plant transformation have been very effective in some species (Fromm et al. 1985; Guerche et al. 1987; Shillito et al. 1985). However, with the exception of work by Dekeyser et al. (1990), electroporation and chemically mediated DNA uptake procedures typically require the removal of cell walls from recipient cells. Such methods may not be useful for groundnut, because plant regeneration from protoplasts has not been reported.

Microprojectile bombardment (Klein et al. 1987; Sanford 1988) has a number of characteristics that make it an attractive alternative to other methods for DNA delivery in groundnut. It has been used successfully to achieve transformation in a number of species, including some of the most recalcitrant (Christou et al. 1988; Finer and McMullen 1990; Fromm et al. 1990; Gordon-Kamm et al. 1990; Iida et al. 1990; Klein et al. 1988; McCabe et al. 1988; Tomes et al. 1990). The biolistic process theoretically allows treatment of any plant tissue. Explant choice can thus be made on the basis of other criteria, such as regeneration potential, favorable metabolic conditions for the expression of a particular genetic construction, or cellular organization that facilitates unambiguous selection of transformants. This simplification has the further advantage that it is likely to facilitate routine application of the system across various groundnut genotypes. Clemente et al. (in press) have observed both transient expression and stable transformation in groundnut tissue bombarded with microcarrier particles carrying plasmid DNA. Appropriate explants to be used as recipient tissue were identified by observing transient expression response in bombarded tissues. Plasmid DNA carrying both the neomycin phosphotransferase (NPT II) (Beck et al. 1982) and beta glucuronidase (GUS) (Jefferson et al. 1987) marker genes, both driven by cauliflower mosaic virus 35S (CaMV-35S) (Benfey et al. 1989) promoters, was precipitated onto gold particles 1 µm in diameter. Particles were delivered into explants from seedlings and mature plants with a helium-powered particle acceleration apparatus. Of the several explants tested, transient expression frequency was highest and most repeatable in unexpanded leaflets and the apical domes of embryonic axes from seedlings bombarded about 4 days after imbibition. (Transient expression 'frequency' refers to the number of independent cell foci that are positive in the GUS histochemical assay (Jefferson 1987) 24 hours after bombardment.)

Evidence from earlier work (Christou 1990; Christou et al. 1989) suggested bombardment of apical meristems could produce transgenic plants, but that the plants tend to be chimeric. Leaflets were also known to regenerate whole plants through primary organogenesis (Mroginski et al. 1981). For these reasons, intact leaflets from 4-day-old seedlings were chosen for subsequent experiments.

Bombarded leaflets gave rise to slow-growing brown callus when plated on a modified Murashige & Skoog medium (Murashige and Skoog 1962) containing 50 mg L^{-1} kanamycin. Rapidly growing chlorophyllous cell masses were also produced on some explants, representing all market types of groundnuts. These green cell clusters continued to grow rapidly when transferred to medium containing 100 mg L^{-1} of the antibiotic. Subsequent assays for NPT II were positive for all of the calli tested. Stable transformation was rigorously proven by both positive results in PCR analysis for the introduced genes, and by DNA-DNA hybridization (Southern blot) analysis. Southern blots demonstrated that both the NPT II and GUS genes were stably integrated in the genomic DNA of all calli. Although all calli tested were positive for expression of the selectable marker (NPT II), only about half of those tested were also positive for expression of the nonselectable GUS marker.

Although several plants have been regenerated from these experiments through primary organogenesis from bombarded leaflets, none has yet proven to be stably transformed (A.K. Weissinger, unpublished data). Stably transformed callus lines remain organogenic, but have thus far failed to produce transgenic plants.

Transgenic plants have been produced in other species by bombardment of such embryogenic cultures (Finer and McMullen 1990; Gordon-Kamm et al. 1990). Very high levels of transient expression have also been observed in embryogenic callus cultures bombarded with gold particles carrying a chimeric CaMV-35S GUS construct (A.K. Weissinger and P. Ozias-Akins, unpublished data). These cultures are capable of high-frequency regeneration through repeated somatic embryogenesis (Ozias-Akins 1989). It appears likely, therefore, that bombardment of embryogenic cultures may be useful for transformation of groundnut.

Genes for groundnut transformation

Genes for groundnut transformation can be divided into those that will be used to overcome limits to production ('agronomic genes') and genes that could be used to enhance the value of the commodity ('value-added traits'). Although manipulation of value-added traits is the ultimate goal of most transformation work, major emphasis is currently being placed on transfer of genes for pest protection. Pest protection can be effected in some instances by the introduction of a single gene. Value-added traits, such as enhanced flavor quality, often depend upon complex interactions between multiple gene products. Transformation strategies for manipulation of such characteristics are not well developed.

Groundnut yields and commodity quality are often reduced by diseases for which no adapted resistant groundnut genotypes are available. These include, for example, virus diseases, such as tomato spotted wilt virus (TSWV), which can sharply reduce groundnut yields (Culbreath et al. 1990). It is possible that groundnut could be protected from TSWV through the expression of virus nucleocapsid protein (J. Moyer, North Carolina State University, personal communication), a strategy which has been proven effective against an array of viral pathogens (Powell Abel et al. 1986).

Infection by other organisms, such as *Aspergillus flavus*, while not always directly damaging to crop yields, may make the commodity unsalable by the production of toxic metabolites. Several transgenic strategies are being considered for reducing aflatoxin contamination in groundnut. Several of these involve either disruption of the infection process, to eliminate the source of toxin, or disruption of aflatoxin synthesis by *A. flavus*.

Chitinases and glucanases are hydrolytic enzymes, isolated from both bacteria and plants, which are potentially useful for protecting crop plants against fungal attack (Dickson 1986). Work is now underway to test variant forms of these enzymes against *Aspergillus* spp, to determine which ones might be useful in transgenic protection strategies for groundnut (T.E. Cleveland, USDA-ARS, personal communication; A.K. Weissinger, unpublished data).

Although many value-added traits appear to be too complex for direct manipulation with current transformation strategies, some work is now being undertaken to alter genes related to groundnut quality. One example is the isolation of genes involved in fatty acid biosynthesis (A. Abbott, Clemson University, personal communication). If altered forms of these genes can be introduced and expressed in transgenic groundnut, it may be possible to control both fatty acid composition and total lipid content of groundnut seeds. Manipulation of these characteristics could lead to the production of groundnuts with extended shelf life and improved nutritional quality.

As described above, molecular marker analysis suggests that little variation exists in the cultivated groundnut. The diploid species, however, are highly variable and are known to carry valuable genetic traits. Transformation may prove useful as an adjunct to interspecific hybridizations for the transfer of useful genes from the wild species into the cultivated groundnut. Gene isolation from the wild species has not yet been reported, however.

Transposon mutagenesis (Baker et al. 1986; Fedoroff et al. 1983) by heterologous transposable elements may prove to be a useful procedure for gene cloning in the wild species, but would likely be of little use for isolating genes from the cultivated species. The presence of homeologous alleles in the tetraploid groundnut would tend to provide redundant copies of genes within the genome. While insertion of a transposable element into a gene is expected to prevent expression of the gene, homeologous genes could continue to express, and would therefore prevent detection of insertion mutations.

The diploid wild species not only carry more diverse germplasm than the cultivated species, but are also better suited for use in a transposon-tagging strategy for gene cloning. Implicit in this assertion is the notion that a transformation system would need to be developed for any species that was to be tagged. However, once the transposon system was introduced into a species, the elements of the system could be transferred sexually to all other germplasm sources with which the transformant was sexually compatible. This would reduce the complexity and cost of transfer of the transposon elements to other genetic stocks.

As transformation systems become more sophisticated, it is expected that their capacity to transfer large segments of DNA will increase. Such a strategy, combined with genes or chromosome segments derived from wild *Arachis* species, may provide a methodology for manipulating complex traits in groundnut. This could prove to be the greatest contribution of transformation technology to groundnut improvement.

References

Atreya, C.D., and **Subrahmanyam, N.C.** 1989. Comparative analysis of repetitive DNA in five *Arachis* species. Biochemical Systematics and Ecology 17:11-13.

Atreya, C.D., Ramakrishna, T., Pandit, M.W., and **Subrahmanyam, N.C.** 1985. Molecular approaches to genome analysis in *Arachis* species. Pages 87-92 *in* Proceedings of an International Workshop on Cytogenetics of *Arachis*, 31 Oct-2 Nov 1983, ICRISAT Center, India. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Atreya, C.D., Rao, J.P., and **Subrahmanyam, N.C.** 1984. In vitro regeneration of peanut (*Arachis hypogaea* L.) from embryo axes and cotyledon segments. Plant Science Letters 34:379-383.

Bajaj, Y.P.S. 1984. Peanuts. Pages 193-225 *in* Handbook of Plant Cell Culture. Vol. 3. Crop Species (Ammirato, P.V., Evans, D.A., Sharp, W.R., and Yamada, Y. eds.). New York, USA: Macmillan Publishing Co.

Bajaj, Y.P.S., Kumar, P., Labana, K.S., and **Singh, M.M.** 1981. Regeneration of plants from seedling-explants and callus cultures of *Arachis hypogaea* L. Indian Journal of Experimental Biology 19:1026-1029.

Baker, B., Schell, J., Lorz, H., and **Fedoroff, N.** 1986. Transposition of the maize controlling element "Activator" in tobacco. Proceedings of the National Academy of Sciences of the United States of America 83:4844-4848.

Beck, E., Ludwig, G., Auersqald, E.A., Reiss, B., and **Schaller, H.** 1982. Nucleotide sequence and exact localization of the neomycin phosphotransferase gene from transposon TN5. Gene 19:327-336.

Benfey, P., Ren, L., and **Chua, N.H.** 1989. The CaMV 35S enhancer contains at least two domains which can confer different developmental and tissue-specific expression patterns. EMBO Journal 8:2195-2202.

Bhatia, C.R., Murty, G.S.S., and **Mathews, V.H.** 1985. Regeneration of plants from "de-embryonated" peanut cotyledons cultured without nutrients and agar. Zeitschrift für Pflanzenzuchtung Journal of Plant Breeding 94:149-155.

Braverman, S.W. 1975. Aseptic culture of soybean and peanut embryonic axes to improve phytosanitation of plant introductions. Seed Science and Technology 3:725-729.

Caestano-Anolles, G., Bassam, B.J., and **Gresshof, P.M.** 1991. DNA amplification fingerprinting using very short arbitrary nucleotide primers. Bio/Technology 9:553-557.

Christou, P. 1990. Morphological description of transgenic soybean chimeras created by the delivery, integration and expression of foreign DNA using electric discharge particle acceleration. Annals of Botany 66:379-386.

Christou, P., McCabe, D.E., and **Swain, W.F.** 1988. Stable transformation of soybean callus by DNA-coated gold particles. Plant Physiology 87:671-674.

Christou, P., Swain, W.F., Yang, N.S., and **McCabe, D.E.** 1989. Inheritance and expression of foreign genes in transgenic soybean plants. Proceedings of the National Academy of Sciences of the United States of America 86:7500-7504.

Clemente, T.E., Beute, M.K., Isleib, T.G., and **Weissinger, A.K.** (In press.) Evaluation of leaflets from mature zygotic embryos as recipient tissue for biolistic gene transfer to peanut (*Arachis hypogaea* L.). Transgenic Research.

Culbreath, A.K., Todd, J.W., and **Demski, J.W.** 1990. Epidemiology of tomato spotted wilt cirus on peanut. Proceedings of American Peanut Research and Education Society 22:81.

Dekeyser, R., Claes, B., De Rycke, R., Habets, M., van Montagu, M., and **Caplan, A.** 1990. Transient gene expression in intact and organized rice tissues. Plant Cell 2:591-602.

Dickson, R.A. 1986. Host antifungal agents. Nature 324:303-304.

Dong, J.D., Bi, Y.P., Xia, L.S., Sun, S.M., Song, Z.H., Guo, B.T., Jiang, X.C., and **Shao, Q.Q.** 1990. Teratoma induction and nopaline synthase gene transfer in peanut. Acta Genetica Sinica 17:13-16.

Fedoroff, N., Wessler, S., and **Shure, M.** 1983. Isolation of the transposable maize controlling elements Ac and Ds. Cell 35:235-242.

Finer, J.J., and **McMullen, M.D.** 1990. Transformation of cotton (*Gossypium hirsutum* L.) via particle bombardment. Plant Cell Reports 8:586-589.

Fromm, M., Morrish, F., Armstrong, C., Williams, R., Thomas, J., and **Klein, T.** 1990. Inheritance and expression of chimeric genes in the progeny of transgenic maize plants. Bio/Technology 8:833-839.

Fromm, M., Taylor, L., and **Walbot, V.** 1985. Expression of genes transferred into monocot and dicot plant cells by electroporation. Proceedings of the National Academy of Sciences of the United States of America 82:5824-5828.

Gordon-Kamm, W., Spencer, T., Mangano, M., Adams, T., Daines, R., Start, W., O'Brien, J., Chambers, S., Adams, Jr., W., Willets, N., Rice, T., Mackey, C., Krueger, R., Kausch, A., and **Lemaux, P.** 1990. Transformation of maize plants and regeneration of fertile transgenic plants. Plant Cell 2:603-618.

Gregory, M.P., and **Gregory, W.C.** 1979. Exotic germ plasm of *Arachis* L. interspecific hybrids. Journal of Heredity 70:185-193.

Gregory, W.C., Gregory, M.P., Krapovickas, A., Smith, B.W., and **Yarbrough, J.A.** 1973. Structures and genetic resources of peanut. Pages 47-133 *in* Peanuts – culture and uses. Stillwater, Oklahoma, USA: American Peanut Research and Education Association.

Guerche, P., Charbonnier, M., Jouanin, L., Tourneur, C., Paszkowski, J., and **Pelletier, G.** 1987. Direct gene transfer by electroporation in *Brassica napus*. Plant Science 52:111-116.

Halward, T.M., Kochert, G.D., LaRue, E.A., and **Stalker, H.T.** 1990. RFLP variability among diverse germplasm resources in peanut. Agronomy Abstracts 1990:197.

Halward, T.M., Stalker, H.T., LaRue, E.A., and **Kochert, G.D.** 1991a. The use of single-primer DNA amplifications in genetic studies of peanut. Page 54 *in*

Abstract of the Symposium on Plant Breeding in the 1990s, 10-14 Mar 1991, Research Report no. 130. Raleigh, North Carolina, USA: North Carolina State University.

Halward, T.M., Stalker, H.T., LaRue, E.A., and **Kochert, G.D.** 1991b. Genetic variation detectable with molecular markers among unadapted germplasm resources of cultivated peanut and related wild species. Genome 34:1013-1020.

Halward, T.M., Stalker, H.T., LaRue, E.A., and **Kochert, G.D.** 1992. Use of single-primer DNA amplifications in genetic studies of peanut (*Arachis hypogaea* L.). Plant Molecular Biology 18:315-325.

Hazra, S., Sathaye, S.S., and **Mascarenhas, A.P.** 1989. Direct somatic embryogenesis in peanut (*Arachis hypogaea*). Bio/Technology 7:949-951.

Iida, A., Morikawa, H., and **Yamada, Y.** 1990. Stable transformation of cultured tobacco cells by DNA-coated gold particles accelerated by gas-pressure-driven particle gun. Microbial Biotechnology 33:560-563.

Illingworth, J.E. 1968. Peanut plants from single de-embryonated cotyledons. Hortscience 3:238, 275-276.

Jefferson, R. 1987. Assaying chimeric genes in plants: the GUS gene fusion system. Plant Molecular Biology Reporter 5:387-405.

Jefferson, R., Kavanaugh, T.A., and **Bevan, M.W.** 1987. GUS fusions: beta-glucuronidase as a sensitive and versatile gene fusion marker in higher plants. EMBO Journal 6:3901-3907.

Klein, T.E., Fromm, M., Weissinger, A.K., Tomes, D., Schaaf, S., Sletten, M., and **Sanford, J.** 1988. Transfer of foreign genes into intact maize cells with high-velocity microprojectiles. Proceedings of the National Academy of Sciences of the United States of America 85:4305-4309.

Klein, T.E., Wolf, E.D., Wu, R., and **Sanford, J.C.** 1987. High velocity microprojectiles for delivering nucleic acids into living cells. Nature 327:70-73.

Kochert, G., Halward, T., Branch, W.D., and **Simpson, C.E.** 1991. RFLP variability in peanut (*Arachis hypogaea* L.) cultivars and wild species. Theoretical and Applied Genetics 81:565-570.

Lacorte, C., Mansur, E., Timmerman, B., and **Cordeiro, A.R.** 1991. Gene transfer into peanut (*Arachis hypogaea* L.) by *Agrobacterium tumefaciens*. Plant Cell Reports 10:354-357.

McCabe, D., Swain, W., Martinell, B., and **Christou, P.** 1988. Stable transformation of soybean (*Glycine max*) by particle acceleration. Bio/Technology 6:923-926.

McKently, A.H., Moore, G.A., and **Gardner, F.P.** 1990. In vitro plant regeneration of peanut from seed explants. Crop Science 30:192-196.

McKently, A.H., Moore, G.A., and **Gardner, F.P.** 1991. Regeneration of peanut and perennial peanut from cultured leaf tissue. Crop Science 31:833-837.

Mroginski, L.A., Kartha, K.K., and **Shyluk, J.P.** 1981. Regeneration of peanut (*Arachis hypogaea*) plantlets by in vitro culture of immature leaves. Canadian Journal of Botany 59:826-830.

Murashige, T., and **Skoog, F.** 1962. A revised medium for rapid growth and bioassays with tobacco cultures. Physiologia Plantarum 15:473.

Oelck, M.M., Bapat, V.A., and **Schieder, A.** 1982. Protoplast culture of three legumes: *Arachis hypogaea, Melilotus officinalis, Trifolium repens*. Zeischrift für Pflanzenphysiologie 106:173-177.

Ozias-Akins, P. 1989. Plant regeneration from immature embryos of peanut. Plant Cell Reports 8:217-218.

Pittman, R.N., Banks, D.G., Kirby, J.S., Mitchell, E.D., and **Richardson, P.E.** 1983. In vitro culture of immature peanut (*Arachis* spp.) leaves: morphogenesis and plantlet regeneration. Peanut Science 10:21-25.

Powell Abel, P., Nelson, R.S., De, B., Hoffman, N., Rogers, S.G., Fraley, R.T., and **Beachy, R.N.** 1986. Delay of disease development in transgenic plants that express the tobacco mosaic virus coat protein. Science 232:738-743.

Resslar, P.M., Stucky, J.M., and **Miksche, J.P.** 1981. Cytophotometric determination of the amount of

DNA in *Arachis* L. sect. *Arachis* (Leguminosae). American Journal of Botany 68:149-153.

Sanford, J.C. 1988. The biolistic process. Trends in Biotechnology 6:299-302.

Sastri, D.C., Nalini, M.S., and **Moss, J.P.** 1982. Tissue culture and prospects for improvement of *Arachis hypogaea* and other oil seed crops. Pages 42-57 *in* Proceedings of the COSTED Symposium on Tissue Culture of Economically Important Plants, 28-30 Apr 1981, Singapore. Singapore: National University of Singapore.

Seitz, M.H., Stalker, H.T., and **Green, C.C.** 1987. Genetic variation for regenerative response in immature leaflet cultures of the cultivated peanut, *Arachis hypogaea*. Plant Breeding 98:104-110.

Sellars, R.M., Southern, G.M., and **Phillips, G.C.** 1990. Adventitious somatic embryogenesis from cultured immature zygotic embryos of peanut and soybean. Crop Science 30:408-414.

Shillito, R., Saul, M., Paszkowski, J., and **Potrykus, I.** 1985. High efficiency direct gene transfer to plants. Bio/Technology 3:1099-1103.

Singh, A.K. 1988. Putative genome donors of *Arachis hypogaea* (*Fabaceae*), evidence from crosses with synthetic amphidiploids. Plant Systematics and Evolution 160:143-151.

Stalker, H.T., and **Eweda, M.A.** 1988. Ovule and embryo culture of *Arachis hypogaea* and interspecific hybrids. Peanut Science 15:98-104.

Sukumar, S., and **Sree Rangasamy, S.R.** 1984. Morphological and growth characteristics of wild and hybrid peanuts (*Arachis* sp) cultured in vitro. Current Science 53:586-588.

Tomes, D.T., Weissinger, A.K., Ross, M., Higgins, R., Drummond, B., Schaaf, S., Malone-Schoneberg, J., Staebell, M., Flynn, P., Anderson, J., and **Howard, J.** 1990. Transgenic tobacco plants and their progeny derived by microprojectile bombardment of tobacco leaves. Plant Molecular Biology 14:261-268.

Williams, J.G.K., Kudbelik, A.R., Rafalski, K.J., and **Tingey, S.V.** 1991. DNA polymorphisms amplified by arbitrary primers are useful as genetic markers. Nucleic Acids Research 18:6531-6535.

Discussion

D.V.R. Reddy: Can you tell us about the nature of probes used in RFLP analysis of *Arachis*? Are there any cloned genes derived from some other legumes?
A.K. Weissinger: Probes used by Dr Kochert and his group were random genomic clones. They were screened to eliminate high-copy number sequences and any one which hybridized to chloroplast DNA was also discarded.

C.S. Busso: What is your opinion on the treatment of the target DNA after polymerase chain reaction with restriction enzymes in terms of sensitivity to methylation?
A.K. Weissinger: Digestion of amplification products with restriction enzymes enhances the resolution of the system. But methylation of DNA complicates the analysis and increases the cost.

S. Chandrapalaiah: Earlier reports expressed that transformation with particle bombardment of somatic embryos resulted in the production of chimeric plants. Do you still suggest that transformation with particle bombardment is reliable?
A.K. Weissinger: The biolistic process does produce chimeric products when target tissue, (e.g., maize embryogenic cultures) have given rise to transgenic plants which are apparently homogeneous. While homogeneous products are, of course, preferable, chimeric transformants have also been used effectively, (e.g., in selective discharge experiments in soybean). Transformation by microprojectile bombardment is reliable if transgenic plants are analyzed properly and used appropriately.

S. Chandrapalaiah: Did you find differential expression of GUS and NPT II in your different stable transformant tissues of groundnut?
A.K. Weissinger: Levels of both gene products varied widely among transgenic callus lines. All selected calluses produced at least low levels of NPT II. While DNA analysis demonstrated the presence of GUS coding sequences in all callus lines, only 50% of these produced GUS, and NPT II did not appear to be correlated.

S.M. Misari: While South America is the place of origin and primary center of diversity of groundnut, the cultivars grown in southern Africa are susceptible to rosette and, interestingly, the sources of rosette-resistant cultivars have their origin in West Africa, to be precise, in Côte d'Ivoire and Senegal. What is the explanation for this situation in terms of the gene pool and gene movement?
H.T. Stalker: The centre of origin is rarely associated with the center of diversity. More specifically to this case, the obvious reason is that natural selection occurred for resistance to rosette virus in a region where the virus is generally found. There would be no natural selection pressure in South America and I would not expect to find resistance there. In groundnut, as well as in many other crop species, there are numerous examples of secondary and tertiary centers of diversity. In groundnut, Africa is the tertiary center of diversity. Thus environmental factors (or natural selection, which is very strong driving force in evolution), presents ample opportunity for evolution of resistant cultivars to rosette or any other disease, insect, etc., where population sizes are great enough for differential survival or reproduction. This is presently the case in Africa.

P.S. Reddy: From the isozyme, RFLP patterns, and other studies, it has been stated that there is not much difference between *Arachis hypogaea* and *A. monticola*. *A. monticola* is also freely crossable with *A. hypogaea*. With this being the case, does *A. monticola* deserve a separate species status? Will it not be more appropriate to call it as a subspecies or a botanical variety of *A. hypogaea*?
H.T. Stalker: A great deal of information has been written regarding species concepts. Based on the 'morphological species' concept, *A. hypogaea* and *A. monticola* are separate species. According to the 'biological species' concept they are the same. For taxonomic purposes, I believe they are morphologically different enough to use the current system of separate names – *A. hypogaea* and *A. monticola*. If *A. monticola* is combined with *A. hypogaea*, then I believe it should be at the subspecies level, not at the variety level. This will not affect the potential use, but is convenient for plant type identification.

J. Smartt: Would it not be a more appropriate illustration of the comparison between isozyme patterns of *Arachis hypogaea* and *A. batizocoi* to use Bolivian landraces rather than NC 4 as the *A. hypogaea* example?
H.T. Stalker: NC 4 was the example used in the study reported here. Because of the uniformity among all *A. hypogaea* genotypes in previous studies, a Bolivian type would have been better for illustrative purposes, but not for genetic studies.

J. Smartt: How extensive has been the range of *Arachis hypogaea* material used in characterizing the isozyme pattern of the cultivated groundnut?
H.T. Stalker: Initial studies centered on American material. Subsequently, a wider range of material from South America was studied which showed a similarly uniform pattern. In fact only a few (three isozymes) were polymorphic among all *A. hypogaea* genotypes studied.

P.S. Reddy: In the interspecific hybridization involving crosses between *Arachis hypogaea* and diploid species of section *Arachis*, what is the pairing behavior of the genomes in the hexaploid hybrids after the doubling of chromosome number? Is there the problem of autosyndetic pairing within the genome and elimination of all species genome subsequently in the derived tetraploids? If so, what methodology should the breeders adopt to make an effective gene transfer from the wild to the cultivated species?
H.T. Stalker: Chromosome behavior at the hexaploid level varies greatly among crosses. Some hexaploids are close to bivalents (and with a few, multivalents), while I have seen crosses with *A. cardenasii* with more than 30 univalents. There is obviously genetic control of chromosome pairing which influences chromosome associations even when homology exists. Based on observations of 40 chromosome hybrid derivatives with obvious gene transfer from the wild species to the cultivated genome, some intergenomic chromosome pairing must occur (presumably at the hexaploid level). The amount of pairing is highly debatable; however, we are currently breeding a set of controlled crosses which will be analyzed with molecular markers in different selfing and backcross generations to detect recombination frequencies. Because of the plant generation time, several years will be necessary to adequately acquire the required data to be more specific.

M.S. Basu: Can ICRISAT/IBPGR provide a databased documentation system to select germplasm on a group of characters rather than the existing system of accession basis?
V. Ramanatha Rao: The present IDMRS system at ICRISAT can retrieve accessions with a specific combination or set of characters and a list can be provided on request.

Modeling Growth and Yield of Groundnut

K.J. Boote[1], J.W. Jones[1], and P. Singh[2]

Abstract

*Crop simulation models have much potential for assisting in agrotechnology transfer, crop management decision-making, climatic assessment, and in the synthesis of research results. For these reasons, it is important to continue to develop and improve models for predicting the growth and yield of groundnut (*Arachis hypogaea*). In this paper, we briefly review approaches for modeling growth and yield of groundnut. Then we illustrate major areas of improvement in the PNUTGRO crop growth model after evaluating PNUTGRO V1.02 versus additional data sets from Florida and India. New areas of improvement include: 1) addition of a hedgerow photosynthesis submodel to improve response to row spacing, sowing density, and growth habit; 2) addition of the Penman equation to incorporate vapor pressure deficit and windspeed to estimate evapotranspiration for arid regions; 3) modification of functions for prediction of crop development; and 4) modification of the effects of stress environments such as high temperature and vapor pressure deficit on partitioning.*

Résumé

***Modélisations de la croissance et du rendement de l'arachide—à la pointe de la technique:** Des modèles de simulation de culture ont beaucoup de potentiel pour aider au transfert d'agrotechnologie, à la prise de décision sur la gestion des cultures, à l'évaluation climatique et à la synthèse des résultats de recherches. Pour ces motifs, il est important de poursuivre les efforts pour développer et améliorer les modèles de production de la croissance et du rendement de l'arachide (*Arachis hypogaea*). Dans cette communication, nous passons brièvement en revue les approches de modélisation de la croissance et du rendement de l'arachide. Ensuite nous illustrons les principales zones d'amélioration du modèle de croissance de culture PNUTRGO après avoir évalué le PNUTGRO V1.02, contre les jeux additionnels de données de Floride et d'Inde. De nouvelles zones d'amélioration comprennent: 1) l'addition d'un sous-modèle de photosynthèse pour améliorer la réponse à l'espacement des rangées, à la densité des semis et leurs habitudes de croissance; 2) l'addition de l'équation Penman pour incorporer le déficit de pression d'eau et la vitesse du vent pour évaluer l'évapotranspiration dans les régions arides; 3) la modification de fonction pour prédire le développement des cultures; 4) la modification des effets des environnements de stress comme les fortes températures et le déficit de pression d'eau sur la répartition.*

1. Professors, Agronomy Department and Agricultural Engineering Department, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, FL 32611-0311, USA.
2. Senior Soil Scientist, Resource Management Program, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, A.P. 502 324, India.

ICRISAT Conference Paper no. CP 806.

Boote, K.J., Jones, J.W., and **Singh, P.** 1992. Modeling growth and yield of groundnut. Pages 331–343 *in* Groundnut – a global perspective: proceedings of an international workshop, 25–29 Nov 1991, ICRISAT Center, India (Nigam, S.N., ed.). Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Groundnut (*Arachis hypogaea*) models have been developed by several groups for different purposes. The first was developed in the early 1970s by W.G. Duncan at the University of Florida for use as a physiological research tool. It was used to evaluate genetic traits influencing yield potential of groundnut (Duncan et al. 1978). Subsequently, Young et al. (1979) published a groundnut growth model based on photosynthesis, growth, and respiration in response to daily environment. In the early 1980s, our group at the University of Florida became interested in dual-purpose uses of crop models for research understanding and crop-management. We initially adapted the SOYGRO model (Wilkerson et al. 1983) to predict growth and yield of groundnut (Boote et al. 1983, 1986). Since that time, we have conducted additional experiments for testing the model. In addition, 4 years of on-farm model testing were conducted to evaluate how well PNUTGRO performs in producer fields under their management practices (Boote et al. 1989a).

Like most crop models, PNUTGRO is process-oriented and considers crop carbon balance, crop nitrogen balance, and soil-plant water balance. In this approach, state variables are the amounts, masses, or numbers of tissues whereas rate variables are the rates of input, transformation, and loss from state variable pools. For example, the crop carbon balance includes daily inputs from photosynthesis, conversion and condensation of carbon (C) into crop tissues, C losses due to abscised parts, and C losses due to growth and maintenance respiration. Crop nitrogen balance considers daily N assimilation, internal mobilization and re-use of N, and N loss in abscised parts. Crop water balance includes infiltration of rainfall and irrigation, soil evaporation, root uptake of water, drainage of water through the root zone, and crop transpiration.

The PNUTGRO model dynamically responds to daily weather inputs (temperature, radiation, rainfall, as well as windspeed and relative humidity if available), soil-water deficit, cultural practices, and cultivar choice. In addition to weather inputs, the model requires soil characterization traits that describe water-holding capacities, runoff, and drainage aspects. Cultural conditions such as sowing date, row spacing, sowing density, harvest date, and cultivar choice can be specified. Different cultivar traits can be simulated. Screen outputs, graphical outputs, and file outputs are available to evaluate outcomes. PNUTGRO is one of a number of models available in the International Benchmark Sites Network for Agrotechnology Transfer (IBSNAT) project. These models have standardized inputs and outputs. PNUTGRO is coded in FORTRAN and runs on most microcomputers.

Description of PNUTGRO Model Features – Old and New

For a more comprehensive overall description of the PNUTGRO model, readers are referred to the paper by Boote et al. (1986). The basic state variable equation approach for crop carbon and nitrogen balance has not been changed. Although C input from photosynthesis is now computed differently, the approaches for dry matter partitioning, growth conversion efficiency, growth respiration, maintenance respiration, and tissue abscission/senescence losses are basically the same. Growth respiration and efficiency of conversion of glucose to plant tissue are computed following the approach of Penning de Vries and van Laar (1982, pp. 123–125). This requires approximate estimates of tissue composition in six types of compounds: protein, lipid, lignin, carbohydrate-cellulose, organic acids, and minerals (summarized by Boote et al. 1986). Maintenance respiration is likewise unchanged, and depends on temperature, crop photosynthesis rate, and on current crop biomass (less oil and protein stored in the seed). Prediction of vegetative and reproductive development is basically the same, although the effects of temperature on development have been changed. The prediction of vegetative and reproductive stages are important, because they describe the crop calendar upon which to predict the partitioning of dry matter to leaf, stem, root, shell, and seed. Partitioning among leaf, stem, and root are dependent on V-stage progression (and water deficit) until flowering. As reproductive development progresses, new sinks (gynophores, podwalls, and seeds) are formed, and assimilate is increasingly partitioned to these tissues rather than to vegetative growth. At the beginning peg (R2) stage, PNUTGRO begins to add new classes or cohorts of reproductive sinks on a daily basis. Fruits of each cohort increase in physiological age and pass through slow and rapid shell growth phases, and at a stage part way through the rapid shell growth phase, seeds in each fruit begin their rapid growth phase. Thus, reproductive "sink" demand comprises many individual reproductive tissues, all of different ages, each having a potential assimilate demand as limited by temperature. The priority for assimilate is seeds first (in order of age), then rapid shell growth, then shells in their slow growth phase, then addition of new gynophores, and lastly, vegetative tissues. A genetic limit of fractional partitioning to pods (XFRUIT) is defined to account for the fact that some groundnut cultivars are indeterminate and continue to grow vegetatively even during rapid seed-filling. Mobilization of protein (C and N) from vegetative tissue begins when seeds begin to grow. The maximum rate of protein mobilization depends on the rate of reproductive development. To the extent that mobilized protein is available, some seeds grow with a reduced conversion cost. The remaining seeds grow with a conversion cost that includes C for nitrate reduction (cost of N_2-fixation is assumed to be the same). As protein is mobilized, leaf photosynthesis and maintenance respiration are reduced and some leaves are abscised. Maturation of this indeterminate crop is problematic since foliage remains green even though growth of progressive cohorts of individual seeds ceases when they reach the limits of their individual pod cavities (maximum shelling percentage). Currently, harvest maturity is called at a given accumulation of physiological days (thermal accumulator).

Other features of PNUTGRO, such as soil water balance, root growth, root water uptake, and stress effects on leaf senescence are unchanged (see Boote et al. 1986).

PNUTGRO Model Improvements

One of the limitations of the last PNUTGRO version was its inadequate response to row spacing and sowing density. A hedgerow light interception-canopy photosynthesis model was developed to overcome this inadequacy. Canopy assimilation is predicted on an hourly basis throughout the day using hourly photosynthetic photon flux density (PPFD) values, computed from the daily radiation integral using a full sine-wave function described by Charles-Edwards and Acock (1977). Hourly temperatures are already computed in the PNUTGRO model for phenology. The hedgerow assimilation model has performed well in predicting field-measured gross canopy assimilation on soybean (*Glycine max*) and groundnut in various row spacings (Boote et al. 1988).

Assimilation by hedgerow canopies

The photosynthesis model was developed by Boote et al. (1988, 1989c) based on a simplification of the hedgerow approach of Gijzen and Goudriaan (1989). The approach considers two classes of leaves, sunlit and shaded. The shadow projected by the canopy is computed as a function of canopy height (H), canopy width (W), time of day, day of year, latitude, and row azimuth. The canopy envelope is defined in the plane perpendicular to the row direction and is assumed to have a height, a width, and an effective curvature of the canopy that is equivalent to a half circle with radius equal to half of the width. Light interception, photosynthesis, and LAI are restricted to the fraction of the soil surface shaded by the canopy, which is a function of the shadow projection, row spacing, and plant spacing in the row. Effects of plant spacing in the row and light reflectance from the soil are also included.

Total hourly incoming PPFD is distributed into a direct component and diffuse component dependent on solar elevation. The PPFD absorbed by sunlit and shaded LAI is computed as described by Spitters (1986). A proportion of the direct beam PPFD is converted to diffuse light within the canopy by scattering processes. Absorption of skylight (diffuse component) is computed following an approach from Goudriaan (1977, pp. 59–63) that uses the path width (alley between hedges), the height and width of the hedgerow, LAI, and a diffuse extinction coefficient of 0.8. Goudriaan's approach assumed that diffuse irradiance originates from a uniformly overcast sky. The average flux of PPFD absorbed by the shaded leaves comes from absorbed skylight and from direct beam converted to diffuse within the canopy. The flux absorbed by sunlit leaves includes diffuse plus direct beam.

Leaf level photosynthesis. Hourly leaf photosynthesis of sunlit and shaded classes of leaves is computed using the asymptotic exponential equation defined by a maximum light-saturated rate (Pmax) and quantum efficiency (QE). The leaf photosynthesis parameters, Pmax and QE, are influenced by temperature and leaf N. With the Pmax and QE parameters, we model leaf photosynthesis response of sunlit and shaded leaves to light, air temperature, and leaf N at each hour of the day, and sum over all leaf area in sunlit and shaded classes to compute hourly canopy assimilation. Hourly assimilation is accumulated to give daily rates. Since soil water and evapotranspiration are computed on a daily basis, water deficit affects daily photosynthesis outside of the hourly loop in the same manner as the present PNUTGRO model.

Photosynthesis response to temperature. The relative response of Pmax to temperature increases linearly from 5° to 25°C (to relative rate of 0.9), achieves an optimum of 1.0 between 28° to 34°C, and declines above 34°C. The QE declines gradually with increasing temperature using an equation that mimics the response reported by Ehleringer and Bjorkman (1977) with a QE = 0.0524 mol mol^{-1} at 30°C. The present equations are valid only for current ambient concentrations of CO_2 and O_2.

Photosynthesis response to leaf N concentration. Data on canopy photosynthesis versus average canopy leaf N concentration (Bourgeois 1989) were used to solve for the shape of leaf photosynthesis decline with N mobilization. Leaf Pmax response to N is modeled with a half parabola described by a minimum N concentration (Nbase = 2.45% N) at which photosynthesis is zero, and an N concentration (Nopt = 5.00% N) at which photosynthesis is maximum. With this new function, there was an improved fit to the late-season decline in canopy photosynthesis for the Florunner cultivar at Gainesville (Fig. 1). Over that same period, N concentration of foliage declined from 4.3 to 3.0%. These changes improved model fit and reduced late-season dry matter accumulation in pod and total crop compared to PNUTGRO V1.02.

Height–width prediction. The hedgerow photosynthesis submodel requires the prediction of canopy geometry. We assumed groundnut has a half circular cross-section perpendicular to the row that can be described by the apparent canopy height and the apparent canopy width. The rate of height and width increase is proportional to the rate of V-stage increase, which in turn is dependent on temperature and water deficit. A "lookup" function was added to the crop parameter file to describe internode length relative to progressive V-stage development. Internode length is additionally dependent on temperature, water deficit, solar irradiance, and photoperiod.

We initially calibrated the rate of vegetative node progression using the Florida data sets. We found it necessary to make minor code changes to allow more rapid node development for the first five nodes expressed. Next, we calibrated the increase in height and width over time with 14 data sets for Florunner in which height and width measurements were taken (Fig. 2). This calibration resulted in an internode length versus V-stage algorithm added to the crop parameter file. A comparison of eight cultivars for V-stage progression at Gainesville in 1990 showed that cultivars do not differ significantly in V-stage progression until late in reproductive growth. The

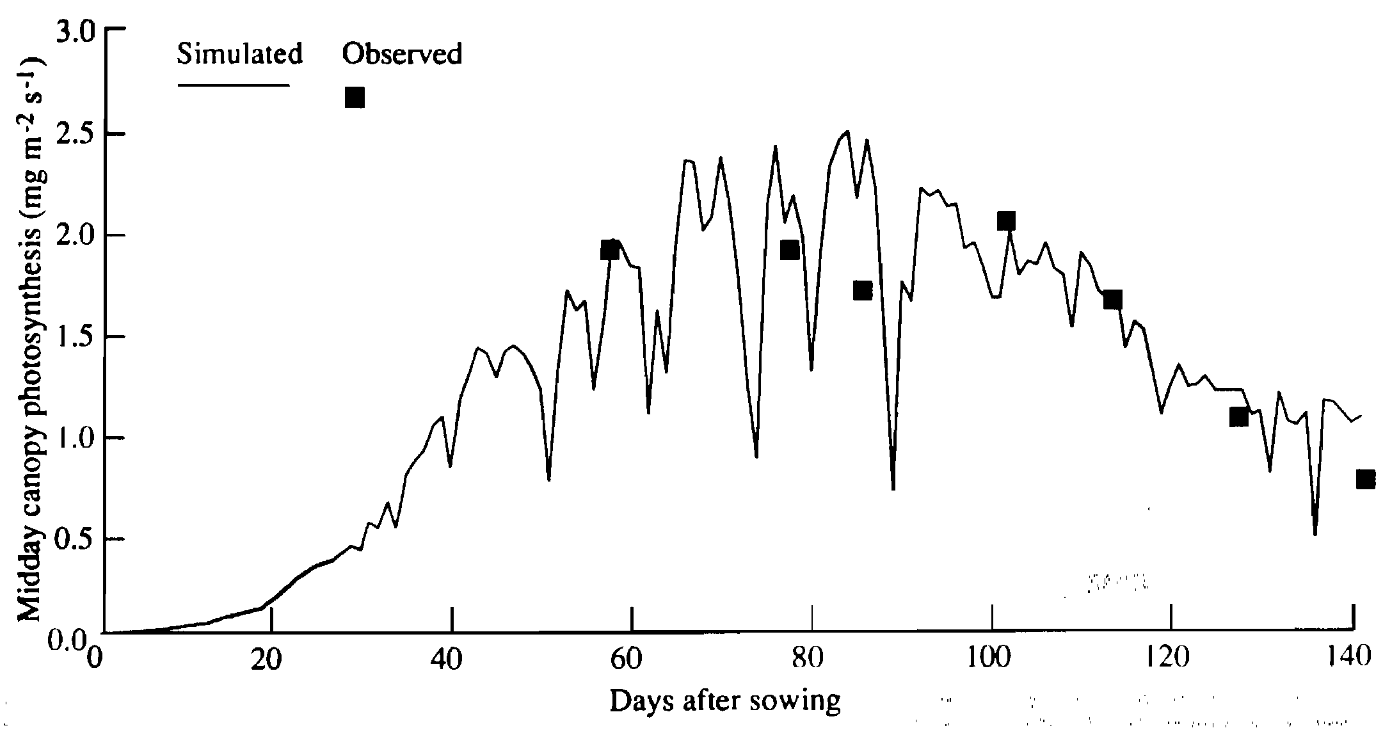


Figure 1. Simulated and observed gross canopy assimilation rate at midday for Florunner during 1986 at Gainesville, showing the effect of declining N mobilization as the crop matured. (Source: Bourgeois 1989.)

V-stage progression of Robut 33-1 (and TMV 2, data not shown) was not different from Florunner (Fig. 3). Height increase likewise did not differ among these three cultivars (data not shown), although width increase was less for TMV 2 and Robut 33-1 compared to Florunner (Fig. 2).

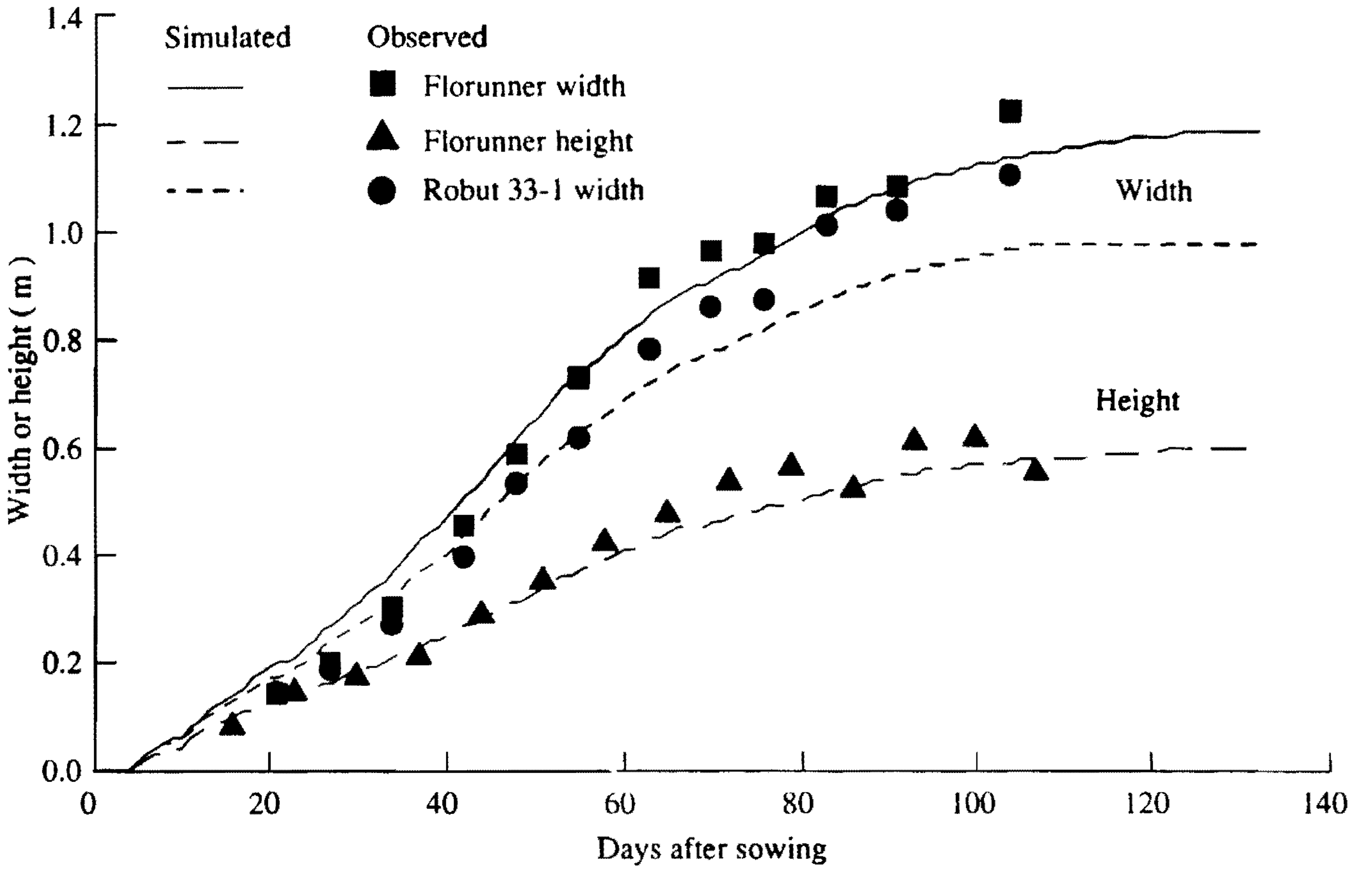


Figure 2. Simulated and observed canopy width and height of Florunner and Robut 33-1 during 1990 at Gainesville. (There was no difference in height between cultivars, hence data ¶for height of Robut 33-1 not plotted.)

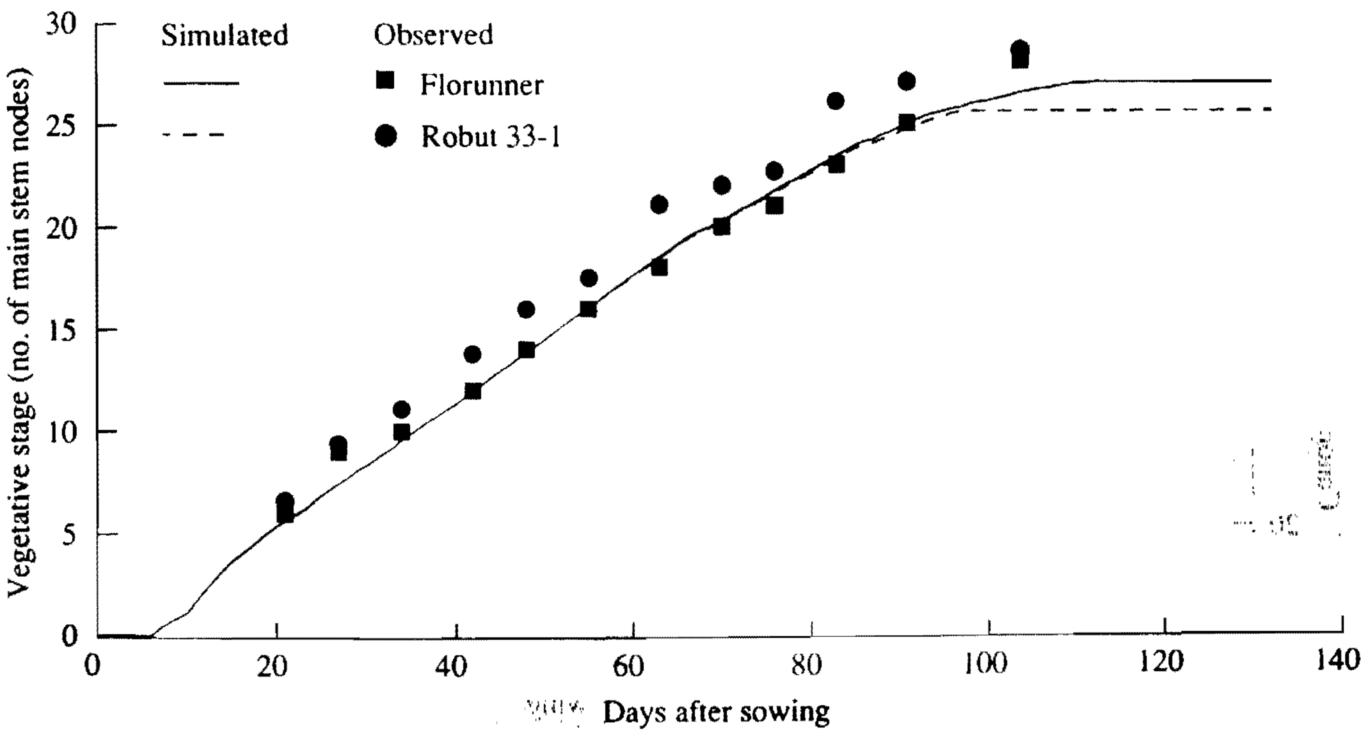


Figure 3. Simulated and observed vegetative stage (main stem node number) of Florunner and Robut 33-1 during 1990 at Gainesville.

Different growth habits of groundnut. Experience with a wide range of genotypes showed the need to account for differences in growth habit: erect bunch type, spreading bunch, or spreading runner type. Simple modifiers were added to the GENETICS.PN9 file to describe genotypes for their relative canopy width or height (RWIDTH or RHIGH), compared to a tall spreading runner type (Florunner standard of 1.0). With this function, we were able to correctly account for the reduced light interception associated with smaller canopy size of erect spanish cultivars such as Chico and Tamnut. Although cultivars differed in crop growth rate because of differences in light interception, we found that radiation use efficiency was not significantly different among eight cultivars during vegetative growth (Ma 1991).

Light interception. With the height and width function calibrated to 14 Florunner data sets and accounting for growth habit, we were able to successfully predict light interception by the crop (Fig. 4).

Simulated response to row spacing. To illustrate the sensitivity of PNUTGRO with the hedgerow photosynthesis submodel, we simulated pod yield response (Fig. 5) for the Robut 33-1 cultivar to row spacings from 0.15 to 3.00 m using 1987 weather data from ICRISAT Center (courtesy, P. Singh). The sowing density per unit land area was held constant at 32.5 plants m^{-2}. The response appears reasonable, but will require validation with experimental data.

Penman evapotranspiration option

The Penman method of computing potential evapotranspiration (E0) was added as an option in PNUTGRO. By specifying the Penman function, the FAO version of the Penman ET equation as described by Jensen et al. (1990) is used to compute E0 through a subroutine call from the soil water balance module. Otherwise, the Priestley-Taylor method that was previously used in PNUTGRO is used. Users can select these methods alternately in the sensitivity analysis mode.

Because the Penman method requires windspeed and humidity data, the weather input subroutine was modified to read daily wind movement (km d^{-1}) and dew point temperature (°C). Thus, if wind movement and dew point temperature (or humidity) data are available, users must add these data to the IBSNAT standard format weather data files. Because these data are unavailable for many locations, defaults are specified in the crop parameter file for windspeed and for the value to subtract from the daily minimum temperature to estimate the day's dew point temperature.

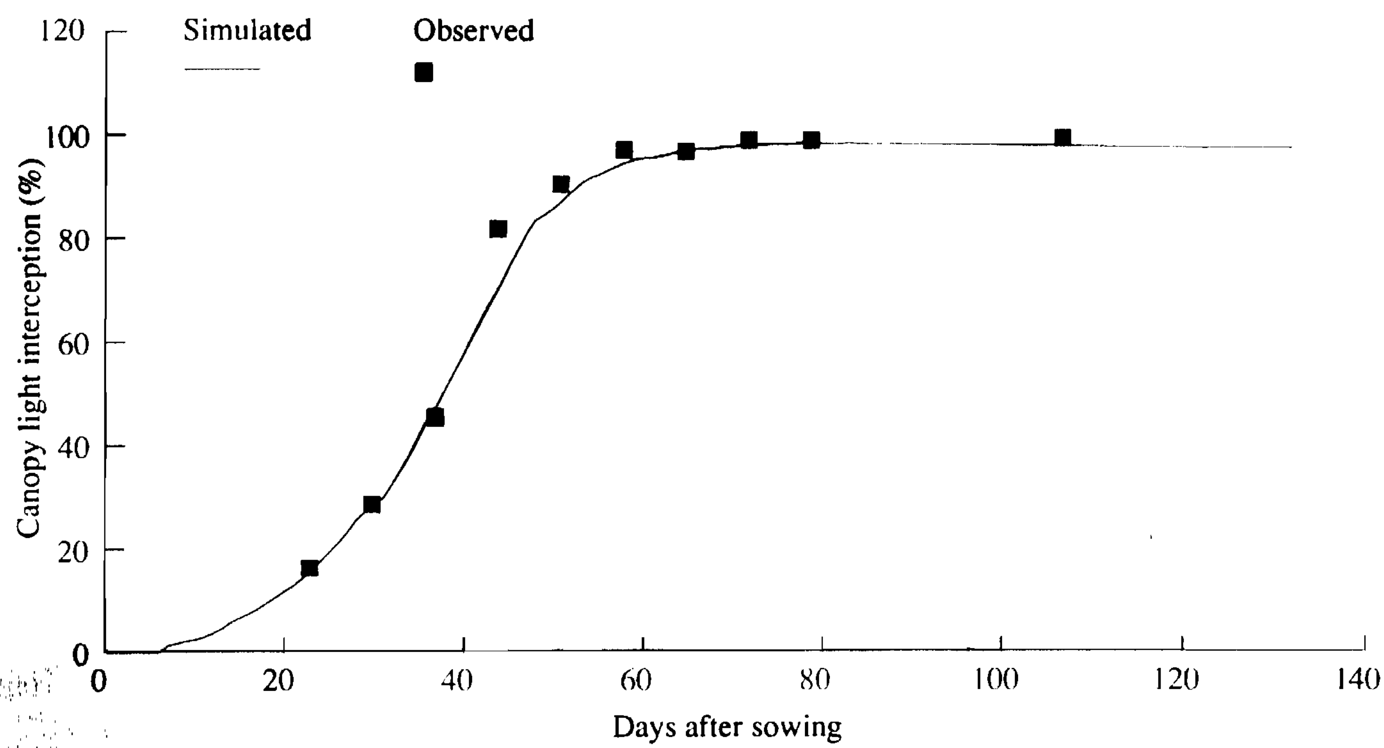


Figure 4. Simulated and observed light interception by Florunner during 1990 at Gainesville. (Source: Observed points from Ma 1990.)

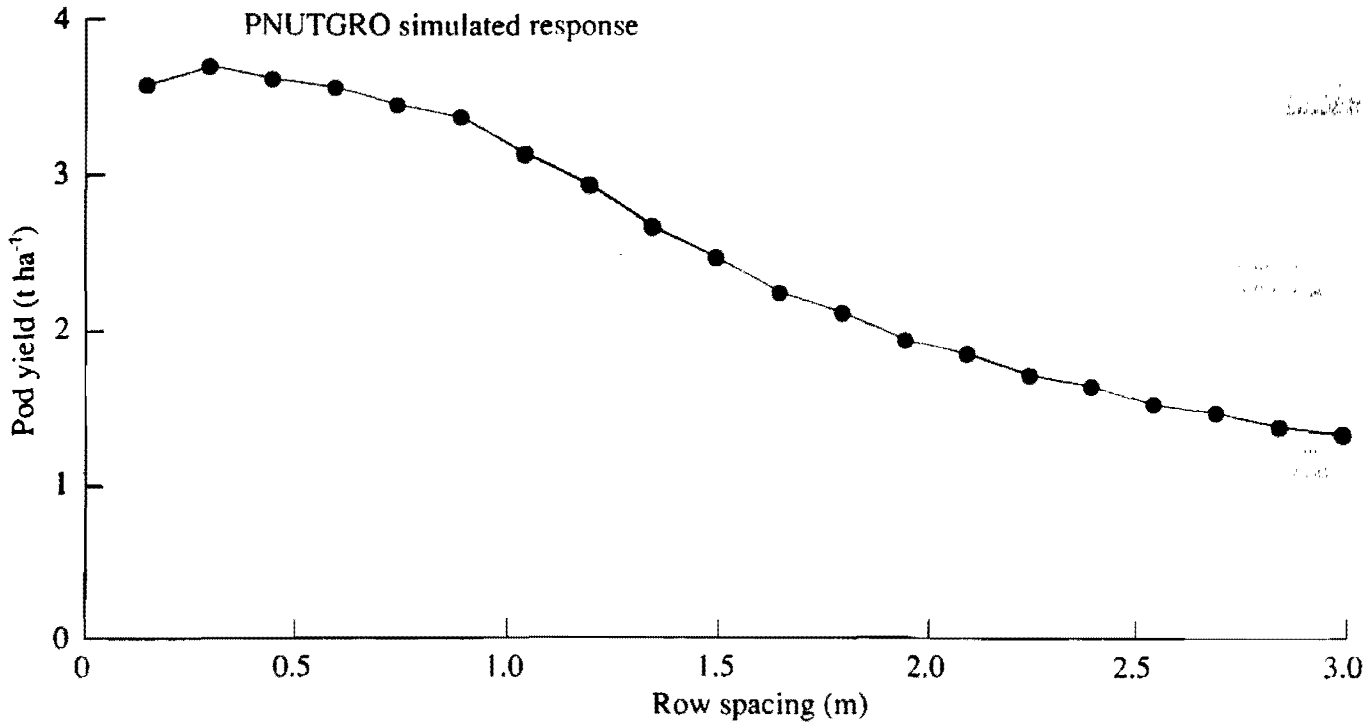


Figure 5. Simulated pod yield in response to row spacing for Robut 33-1 in 1987 at ICRISAT Center. The number of plants per unit area was constant at 32.5 plants m^{-2}.

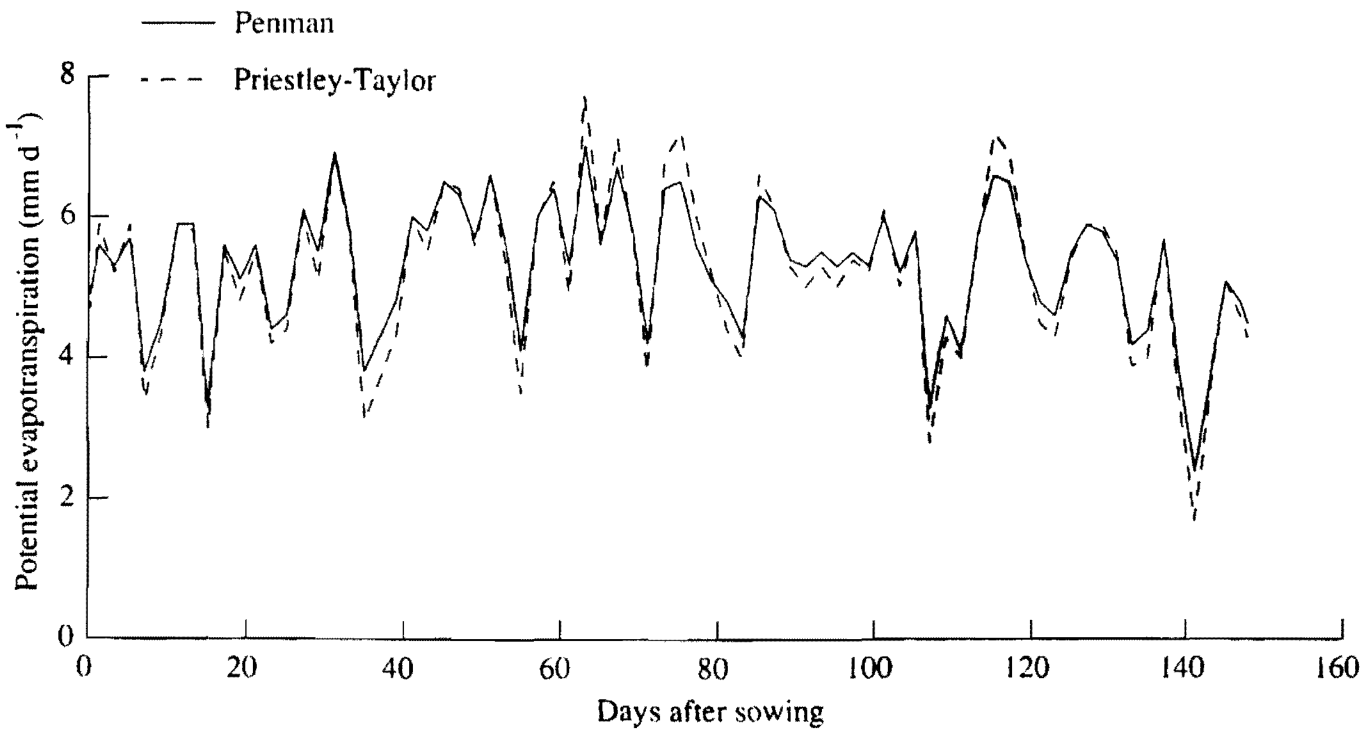


Figure 6. Potential evapotranspiration for Florunner predicted by the Penman and Priestley-Taylor functions during 1981 at Gainesville.

In humid areas, this value is usually between 0.0 and 1.0°C.

With a default windspeed of 2 m s^{-1} and the default method for estimating dew point temperature, the Penman ET function produced very similar ET to the Priestley-Taylor function in Gainesville (Fig. 6) and actually created less ET in midsummer at the Hisar location in India. Unless actual windspeed and humidity are available, there is no advantage in using the Penman function.

Crop development and phenology

The prediction of crop development and ontogeny is important because the onset of new organs dictates where assimilate is partitioned. The new version predicts the progressive development of vegetative and reproductive stages of groundnut as defined by Boote (1982). The V and R development stages are used in the model to influence height-width increase, partitioning among plant parts, pod addition, seed addition, and the beginning of N remobilization.

In version V1.02 of PNUTGRO (Boote et al. 1989b), a broken linear function (Tbase = 11, Topt = 28, Topt2 = 32, and Tmax = 55) was used to describe both vegetative and reproductive development. Experience with Florida and India data showed this function to be inadequate for reproductive development; simulated reproductive development proceeded too slowly at moderate temperature and too rapidly at high temperature. In particular, maturity was unrealistically delayed in late fall. We propose that reproductive response to temperature differs from that of vegetative development in at least two ways: 1) there is a curvilinear component in the response to temperature as shown by Bagnall and King (1991a), and 2) the base and optimum temperature for reproductive development may shift to lower values as the crop sets pods.

Based on limited data on the Florunner cultivar in Florida (17 observations on days to flower), we also concluded that progress toward flowering has a nonlinear component and is better fitted by the full sine function than by linear, broken linear, or the Bagnall and King parabolic function. In fact, fit by all models was improved if developmental rate was allowed to be reduced at high temperature. Fitted values for the full sine function gave a Tbase of 14.5°C and Topt of 26.5°C and standard deviation of 2.71 days. Because our data did not span far enough into the range of cool temperatures, we did not trust the solved Tbase for general use, we decided to keep the Tbase of 11°C and Topt of 28°C as consistent with Ong (1986) and Fortanier (1957).

The new version of PNUTGRO uses three temperature functions for crop development: 1) the previous broken linear function for V-stage progression, 2) the full sine function for reproductive development until seed growth begins at the R4-R5 stage, using a Tbase = 11°C and Topt = 28°C, with slower development above 28°C, and 3) the full sine function from beginning seed growth to maturity with Tbase = 5°C and Topt = 26°C. There is still insufficient information on how temperature affects rate of reproductive progress of groundnut during seed filling.

Effects of stress environments

It is important to test crop models over a wide range of environments. In testing PNUTGRO with 11 growth analyses on the Florunner cultivar in Florida, we found model misfits in some of the years/environments. Since the cultivar was the same and soil type was common across years (10 sets on the same research location/soil type), we could not attribute differences to genotype or soil type, but were forced to look closely at weather effects. It is too easy (and often incorrect) to attribute differences to a new cultivar and/or a new soil fertility factor when, in fact, the cultivar or soil may not differ.

An evaluation of weather associated with poor predictions of reproductive growth in Florida suggested that pod addition and intensity of partitioning to pods were slowed down by either high temperature or high vapor pressure deficits. The same situation (slower pod growth, greater vegetative growth) was observed for hot, arid environments in India (Haryana and Punjab as contrasted to Tamil Nadu). Gramme Hammer (personal communication, 1990) has also observed an association of lower partitioning (rate of increase in harvest index) and prolonged vegetative growth at higher temperature. Thus, we developed an algorithm to allow daily maximum temperature (Tmax) and/or long days to reduce partitioning (XFRUIT) and pod addition rate (PODVAR). The Tmax was used rather than hourly or mean temperature because days with high Tmax frequently had lower minimum temperatures, thus creating little difference in average temperature. This function was calibrated to the 11 research data sets and several on-farm data sets of Florunner. The best fit resulted with a function that reduced partitioning and pod addition when Tmax was greater than 33°C, with a linear decline in relative rate to 0.4 at 46°C. This change also forced a slight re-calibration in the standard values for XFRUIT and PODVAR because these now become defined when Tmax is less than 33°C. The XFRUIT value for Florunner increased from 0.85 to 0.90 and PODVAR increased from 15.0 to 16.0 pods m^{-2} day^{-1}. XFRUIT and PODVAR both affect rate of pod addition, but XFRUIT additionally defines the maximum fraction of daily plant assimilate that is allocated to pod growth.

The temperature effect also worked well for the Indian data sets, but we additionally added a photoperiod effect on rate of pod addition and partitioning for the Robut 33-1 and TMV 2 cultivars, which resulted in a better fit to data spanning north to south in India and spanning from early to late summer sowing.

Long days were shown by Bagnall and King (1991b) to reduce flower, peg, and pod numbers on Robut 33-1.

We also evaluated effects of dry pegging zone soil and low plant turgor on pod addition. We developed a function to compute the fraction of water available in a variable depth of topsoil. The best depth was about 20 cm. Shallower depths were unstable for computing pegging zone soil water content because of unrealistically rapid evaporation from the soil surface. The best function was a relative pod addition rate of 0.0 to 1.0 as soil water availability increased from 0.01 to 0.25, and a rate of 1.0 above that point. In the pod addition function, we took the minimum of this function or the SWFAC (ratio of root water supply to potential climatic transpiration). This function resulted in slight delays in rate of pod addition for several drought treatments, while creating minimal effect on well-irrigated treatments. The effect of this function was intentionally made weak since recent evidence suggests that Florunner and Robut 33-1 will produce pods in air-dry soil although at a slower rate.

Water deficit effects (SWFAC) were further allowed to delay progression toward the following reproductive stages: beginning peg (R2), beginning pod (R3), and beginning seed (R4-5). There were only small effects from these changes with the Florida data sets.

For the Florida data sets, the hedgerow version of PNUTGRO predicted less water deficit during early season than the previous version and did not correctly predict the relative drought effects, even with the addition of the Penman ET equation. We compared predicted to observed root length density for four Florida data sets and concluded that the model was overpredicting the total root length density (RLD) and that the predicted profile distribution placed too much RLD at depth. A comparison of partitioning to a 1984 data set suggested that relative partitioning to root mass was correct up to 42 days. Thus, we took the simple approach to reduce RFAC1, root length per unit mass, from 6550 to 4550 cm g^{-1}. To better predict the observed profile, the RLD function for Florida sandy soils was changed to produce more RLD in the upper 30 cm and approximately one-third less RLD below 30 cm as compared to the previous function. With these changes, better fits to rainfed treatments were obtained and effects of drought were more realistically simulated. It is unfortunate but realistic that minor changes in rooting in deeper layers have an important impact on ability to predict drought consequences.

Automatic sowing for strategy evaluation

In simulating groundnut production for several years to estimate the variability in production due to weather uncertainty, it is not realistic to sow the crop on the same day each year. The soil may be too dry on the intended sowing day (or too wet) and thus sowing would have to be delayed. An option for the strategy evaluation mode was added to delay sowing beyond the input sowing date, if soil water in the top 30 cm is too low or too high (less than 50% or greater than 100% of available soil water). In the latter case (greater than 100%), sowing is delayed because soil water is above the drained upper limit.

Scheduled harvest date

Physiological maturity in groundnut is not as clearly defined nor as discrete as in other crops such as *Glycine max* and *Zea mays*. Pod addition is more gradual in groundnut than in other crops, vegetative growth continues during the seed growth phase, and there are pods of various ages when the crop is harvested. In the field, abscission of mature pods will occur if harvest is delayed too long (the current model does not account for pod losses). As a result, predicting harvest date is very difficult, and harvested yield depends on this date to a large extent. To provide a more straightforward comparison with observed harvest data, an option was added to PNUTGRO to force harvest on the date that the experimental crop was actually harvested. Otherwise, the model stops when the simulated maturity is achieved. For strategy evaluation runs, the model always stops at the simulated date of maturity.

PNUTGRO Simulations in Florida and in India

The predictions of pod and total crop growth were quite successful for well-managed research plots at Gainesville, Florida (Fig. 7), where fertility was good and optimum pest-control practices were followed. Most of these treatments were irrigated, so the Florida data did not span far into stressful environments. For the India data, we found a wider range of environments including greater drought stress. Drought at ICRISAT Center in 1987 greatly reduced dry matter accumulation in total crop and pod of Robut 33-1 compared to the irrigated treatment (Fig. 8). Crop and

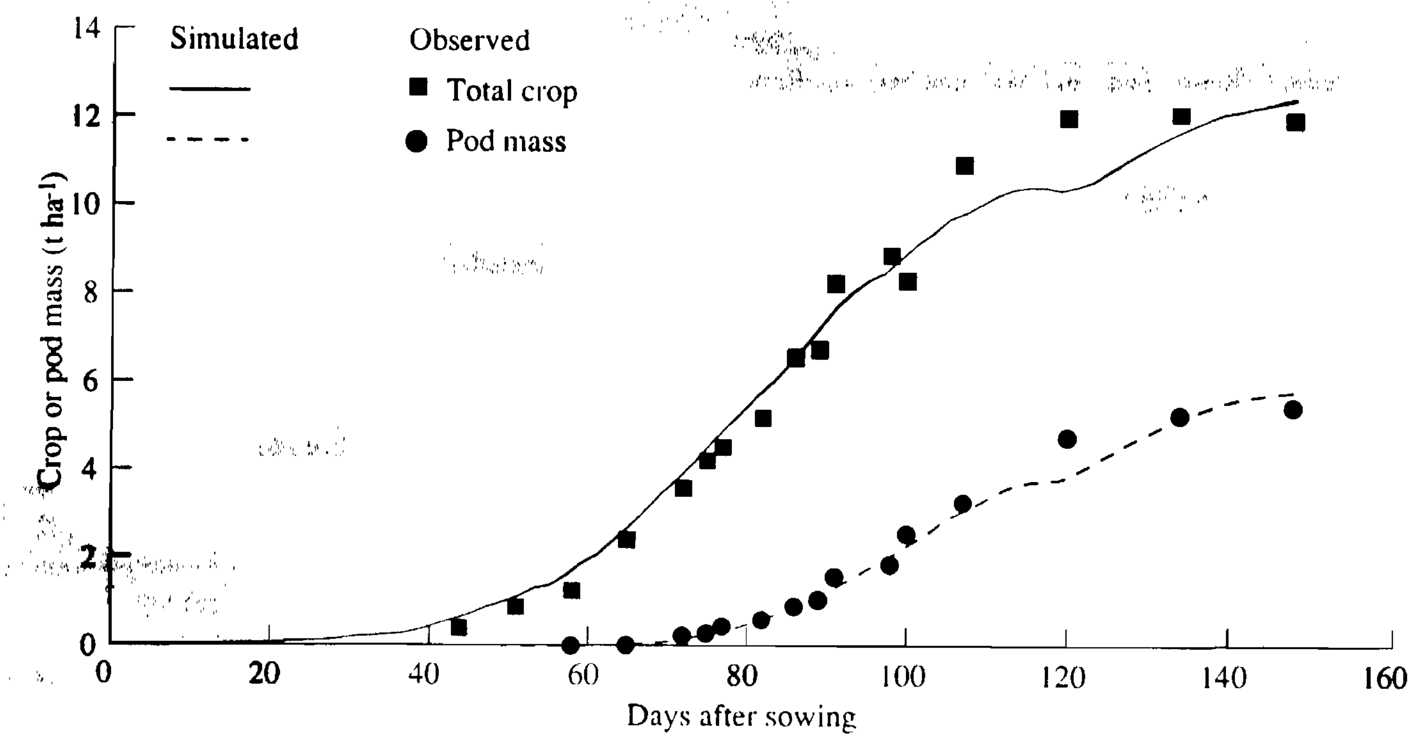


Figure 7. Total crop biomass and pod mass for Florunner in 1981 at Gainesville.

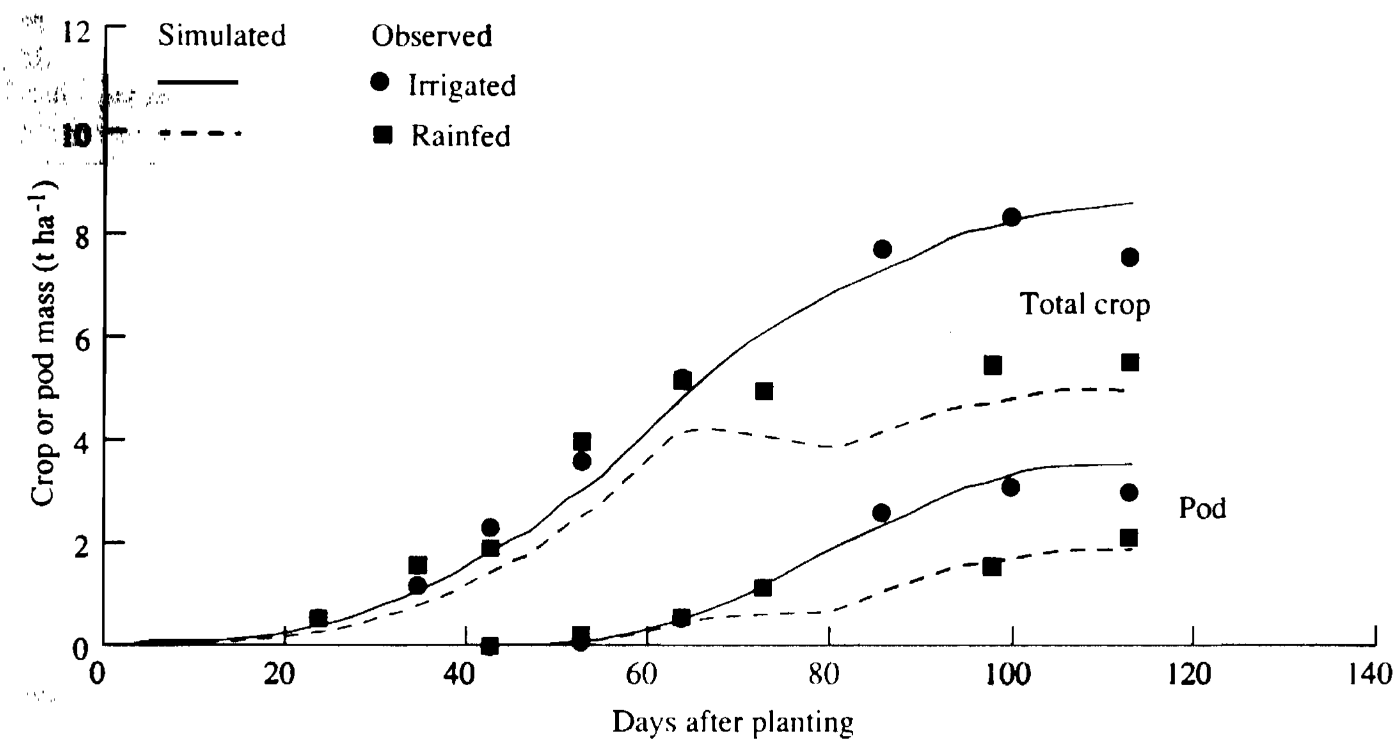


Figure 8. Total crop biomass and pod mass for irrigated and rainfed Robut 33-1 grown in 1987 at ICRISAT Center.

pod growth of Robut 33-1 were also reduced for the rainfed treatment at Anand, India, in 1987 (Fig. 9). The apparent good model fits in these three examples must be tempered by the fact that we calibrated the Florunner cultivar (one common set of genetic traits) for 11 Florida data sets, and the Robut 33-1 cultivar for 19 data sets over 7 sites. The soil fertility (site) factor was set at 1.00 for Gainesville, 0.94 for ICRISAT Center, and 1.05 for Anand. After the calibration for Robut 33-1 (19 growth analyses over 6 sites), the PNUTGRO model was able to account for 71% of the pod yield variation (Fig. 10). At the Ludhiana site (5

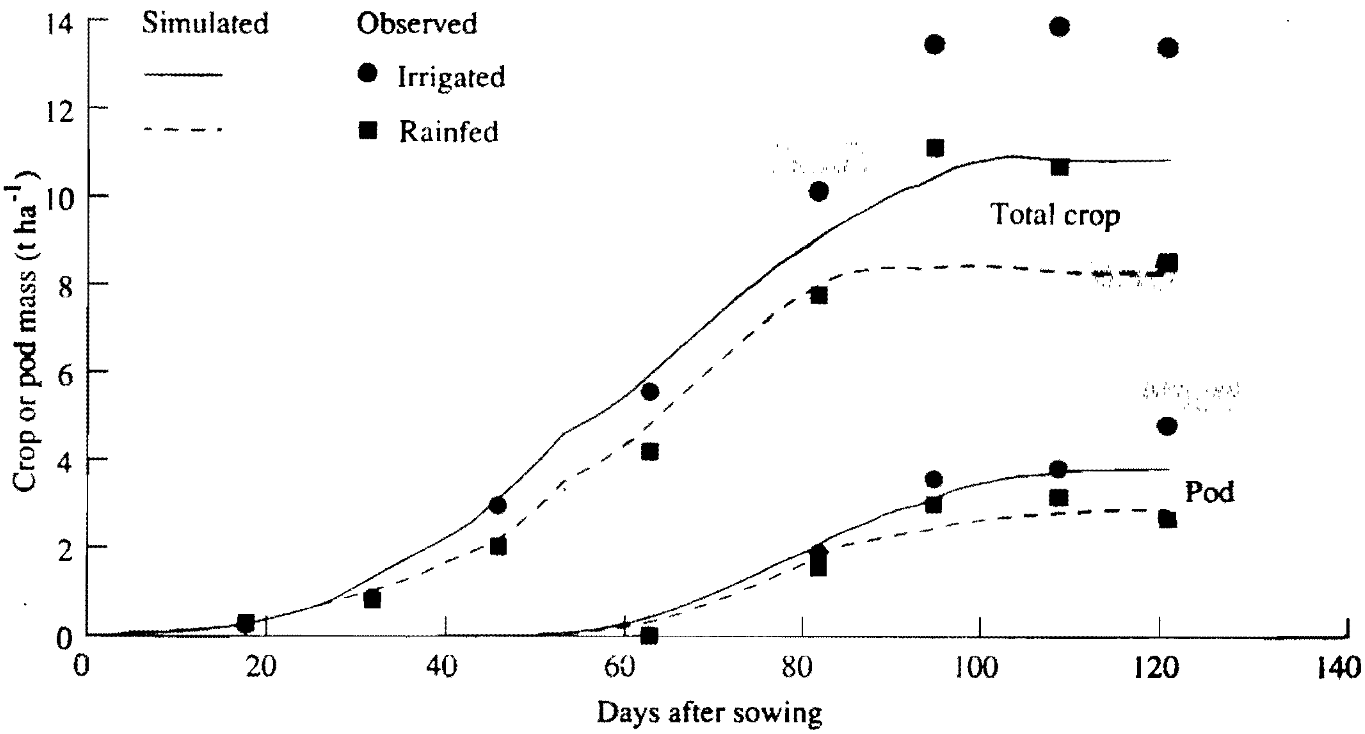


Figure 9. Total crop biomass and pod mass for irrigated and rainfed Robut 33-1 grown in 1987 at Anand, India.

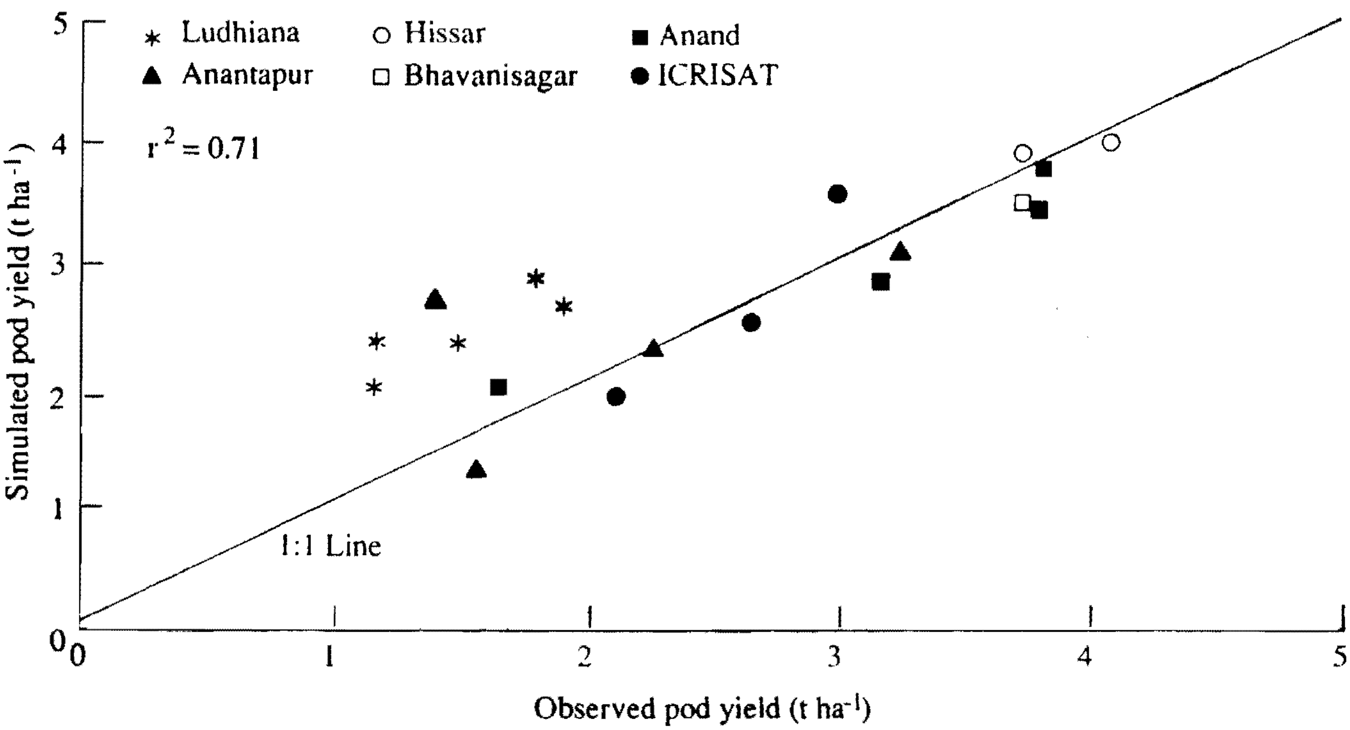


Figure 10. Simulated versus observed final pod yield for Robut 33-1 grown in 19 treatments at 6 sites in India in 1987.

of 19 data sets), the model over-estimated pod yield even though it was correct on biomass accumulation. There appeared to be a problem with partitioning to pods at that site. Serious over-estimation of rainfed yield at Anantapur was attributed to uncertainty of initial soil water below 45 cm and unknown probability of roots below that depth. The more important test of PNUTGRO predictability is still to come when we validate the new version against new data (1988–1991) for the same locations, without changing cultivar or soil traits.

Potential yields, actual yields, and limitations from pests and infertility

It is important to realize that PNUTGRO is programmed to respond to climatic and soil water limitations, but that it does not presently consider pest or soil fertility limitations. (This is true of most crop models.) Our on-farm experience with groundnut producers in Florida over the past 4 years has shown that many grower fields do not achieve the climatic production potential because of diseases, insects, nematodes, and other soilborne pests. Similarly, we found many situations in the India data in which actual growth and yield were less than the predicted (climatic potential) growth and yield. In many cases, climate was probably not a limiting factor, but poor growth may have been associated with low fertility, soilborne pests, and poor foliar disease and insect control. We are not sure how well these factors were controlled in the India data sets. Actually, this comparison of actual growth and yield to potential may provide a useful assessment tool that illustrates how much yield one should have obtained if there were no disease or insect pests and if there were no soil fertility limitations. In this way, models can be used to highlight nonclimatic limitations to yield. They can give researchers a target yield that should be attainable, provided soil and pest limitations can be discovered and then minimized.

Work in Progress

Work in progress includes efforts to add effects of soil phosphorus to all IBSNAT models, and soil N processes to the PNUTGRO and SOYGRO models. A future PNUTGRO version will have sensitivity to carbon dioxide for use in global climate change studies. We are developing a generic 'pest coupling' approach for the IBSNAT crop models including PNUTGRO, whereby the observed pest damage can be entered into a file and the model run to evaluate potential yield loss from the pest. This approach requires 'scouting' data inputs, but it does not require mechanistic models of the pests. Lastly, we are attempting to develop a simple primary set of modeled 'genetic' traits so we can mimic growth and yield of different groundnut genotypes. The ability to evaluate hypothetical cultivar traits with the PNUTGRO model is a potentially valuable tool to determine the best adaptation in new climatic regions (Boote and Jones 1988).

References

Bagnall, D.J., and **King, R.W.** 1991a. Response of peanut (*Arachis hypogaea*) to temperature, photoperiod and irradiance. 1. Effect on flowering. Field Crops Research 26:263-277.

Bagnall, D.J., and **King, R.W.** 1991b. Response of peanut (*Arachis hypogaea*) to temperature, photoperiod and irradiance. 2. Effect on peg and pod development. Field Crops Research 26:263-277.

Boote, K.J. 1982. Growth stages of peanut (*Arachis hypogaea* L.). Peanut Science 9:35-40.

Boote, K.J, and **Jones, J.W.** 1988. Applications of, and limitations to, crop growth simulation models to fit crops and cropping systems to semi-arid environments. Pages 63-75 *in* Drought research priorities for the dryland tropics (Bidinger, F.R., and Johansen, C., eds.). Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Boote, K.J., Bennett, J.M., Jones, J.W., and **Jowers, H.E.** 1989a. On-farm testing of peanut and soybean models in North Florida. Paper no. 89-4040. St. Joseph, Michigan, USA: American Society of Agricultural Engineers.

Boote, K.J., Bourgeois, G., and **Goudriaan, J.** 1988. Light interception and photosynthesis of incomplete hedgerow canopies of soybean and peanut. Agronomy Abstracts 1988:105.

Boote, K.J, Jones, J.W., and **Hoogenboom, G.** 1989c. Simulating crop growth and photosynthesis response to row spacing. Agronomy Abstracts 1989:11.

Boote, K.J, Jones, J.W., Hoogenboom, G., Wilkerson, G.G., and **Jagtap, S.S.** 1989b. PNUTGRO V1.02, peanut crop growth simulation model, user's guide. Gainesville, Florida, USA: Florida Agricultural Experiment Station, 76 pp.

Boote, K.J., Jones, J.W., Mishoe, J.W., and **Berger, R.D.** 1983. Coupling pests to crop growth simulators to predict yield reductions. Phytopathology 73:1581-1587.

Boote, K.J., Jones, J.W., Mishoe, J.W., and **Wilkerson, G.G.** 1986. Modeling growth and yield of groundnut. Pages 243-254 *in* Agrometeorology of groundnut: proceedings of an International Symposium, 21-26 Aug 1985, ICRISAT Sahelian Center, Niamey, Niger. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Bourgeois, G. 1989. Interrelationships between late leaf spot disease and Florunner peanut: a modeling approach. Ph.D. thesis, University of Florida, Gainesville, Florida, USA. 219 pp.

Charles-Edwards, D.A., and **Acock, B.** 1977. Growth response of a *Chrysanthemum* crop to the environment. II. A mathematical analysis relating photosynthesis and growth. Annals of Botany 41:49-58.

Duncan, W.G., McCloud, D.E., McGraw, R.L., and **Boote, K.J.** 1978. Physiological aspects of peanut yield improvement. Crop Science 18:1015-1020.

Ehleringer, J., and **Bjorkman, O.** 1977. Quantum yields for CO_2 uptake in C_3 and C_4 plants: dependence on temperature, CO_2, and O_2 concentration. Plant Physiology 59:86-90.

Fortanier, E.J. 1957. Control of flowering in *Arachis hypogaea* L. Mededelingen Landbouwhogeschool Wageningen 1957:1-116.

Gijzen, H., and **Goudriaan, J.** 1989. A flexible and explanatory model of light distribution and photosynthesis in row crops. Agricultural and Forest Meteorology 48:1-120.

Goudriaan, J. 1977. Crop micrometeorology: a simulation study. Wageningen, Netherlands: PUDOC (Centre for Agricultural Publishing and Documentation). 249 pp.

Jensen, M.E., Burman, R.D., and **Allen, R.G.** (eds.) 1990. Evapotranspiration and irrigation water requirements: a manual. New York, USA: American Society of Civil Engineers. 332 pp.

Ma, L. 1991. Physiological traits contributing to yield potential in peanut genotypes. M.S. thesis, University of Florida, Gainesville, Florida, USA. 179 pp.

Ong, C.K. 1986. Agroclimatological factors affecting phenology of groundnut. Pages 115-125 *in* Agrometeorology of groundnut: proceedings of an International Symposium, 21-26 Aug 1985, ICRISAT Sahelian Center, Niamey, Niger. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Penning de Vries, F.W.T., and **van Laar, H.H.** 1982. Simulation of growth processes and the model BACROS. Pages 114-136 *in* Simulation of plant growth and crop production. Wageningen, Netherlands: PUDOC (Centre for Agricultural Publishing and Documentation).

Spitters, C.J.T. 1986. Separating the diffuse and direct component of global radiation and its implication for modeling canopy photosynthesis. Part II. Calculation of canopy photosynthesis. Agricultural and Forest Meteorology 38:231-242.

Wilkerson, G.G., Jones, J.W., Boote, K.J., Ingram, K.T., and **Mishoe, J.W.** 1983. Modelling soybean growth for crop management. Transactions of the ASAE 26:63-73.

Young, J.H., Cox, F.R., and **Martin, C.K.** 1979. A peanut growth and development model. Peanut Science 6:27-36.

Concepts for the Application of Crop Physiological Models to Crop Breeding

J.H. Williams[1]

Abstract

Many difficulties in the plant breeding process may be attributed to genotype by environment interactions. The present solutions to many of these problems are scientifically empirical and economically costly. Crop physiological models have the potential to be a tool in improving the plant breeding process. The challenge in applying crop models to breeding has been getting the data needed for these models. For simulation models the input parameters generally are very extensive, which means that they cannot be applied to selection among the large numbers of lines handled in a breeding program. However, simpler crop physiological models involving only a few parameters, derived from nondestructive observation, have the potential to greatly improve the efficiency of breeding processes without major changes in data capture and processing capabilities. The techniques advocated can be applied to both improving selection techniques and exploiting the lines generated.

Résumé

Concepts d'application de modèles physiologiques de culture pour la sélection des cultures: *Bien des difficultés dans le processus de sélection végétale peuvent être attribuées aux effets des variations d'environnement et des génotypes qui répondent différemment aux divers environnements. Les solutions actuelles d'un grand nombre de ces problèmes sont scientifiquement empiriques et économiquement coûteuses. Les modèles physiologiques de culture sont potentiellement des outils pour améliorer le processus de sélection végétale. La difficulté pour appliquer les modèles de culture à la sélection a été l'obtention de données nécessaires pour cette modélisation. Pour les modèles de simulation, les paramètres d'intrants sont généralement vastes et cela signifie qu'ils ne peuvent pas être appliqués à la sélection parmi les grands nombres de lignées traitées dans un programme de sélection. Toutefois, des modèles physiologiques de cultures simples, n'impliquant que quelques paramètres et dérivés d'observations non destructives ont un potentiel pour améliorer largement l'efficacité des processus de sélection sans provoquer de grands changements de la saisie des données et du potentiel de traitement. Les techniques recommandées peuvent être appliquées tant à l'amélioration des techniques de sélection qu'à l'exploitation des lignées formées.*

1. Principal Crop Physiologist, Resource Management Program, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), ICRISAT Sahelian Center, B.P. 12404, Niamey, Niger (via Paris).

ICRISAT Conference Paper no. CP 807.

Williams, J.H. 1992. Concepts for the application of crop physiological models to crop breeding. Pages 345–352 *in* Groundnut – a global perspective: proceedings of an international workshop, 25–29 Nov 1991, ICRISAT Center, India (Nigam, S.N., ed.). Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

For logistical reasons breeding for yield is often subjective in the initial phases, and later becomes a largely empirical procedure. This occurs because of the limitations to obtaining better data and details about the processes involved in yield determination in the numbers appropriate to a breeding program. It is by quantifying (and exploiting the known facts about) the yield-determining processes that improvements in breeding efficiency can be obtained.

Models are not new concepts to crop breeders who have exploited other models for many years. A model (Equation 1, attributed to Fisher, 1926) that all breeders are familiar with provides a good basis for discussion of the problems. This model applies equally to single plant and crop level yield variations. Basic to most breeding practices is the acceptance of the phenotype model of yield:

$$Y_T \text{ or } Y_R = G + E + G.E + \delta \qquad (1)$$

which defines total yield (Y_T) or reproductive yield (Y_R) as being due to the sum of the effects of

(G) genetic,
(E) environmental,
($G.E$) genotype by environment interactions, and
(δ) error components.

Crop improvement by genetic manipulation is an expensive and time-consuming process. A major reason for the high cost of the process is the effect of variations of both E and differential genotype response to varying environments ($G.E$) on plant performance. In terms of this model, a low heritability of a characteristic (such as yield) indicates that G is relatively small compared with E and $G.E$. This means that selection for traits such as these is unreliable and inefficient in early generations. The present breeding solution to this problem is to exert low selection pressure on traits such as yield (with the attendant cost increase). The possibility of genotypes responding differently to variations in E requires the breeder to evaluate the material in many environments to permit estimations of the three components of the model (again, a very costly procedure). Even when multilocational trials are conducted, the existence of a large $G.E$ term in the model without information concerning its physiological basis leaves the breeder without a clear idea of how to further exploit the material. However, better knowledge of the physiological basis for the differential responses of genotypes to specific environments offers the potential to maximize yield at the farm level by better exploitation of the appropriate specific varieties (Williams and Saxena 1991).

Technologies that can allow the contributions of E to yield to be better estimated should improve the efficiency with which the breeder can characterize material for its G and $G.E$ interaction, and should greatly increase the speed with which new varieties are produced.

This paper uses groundnut (*Arachis hypogaea*) as a model crop species, but the approach and tools used have an equally important role in other crops [e.g., chickpea (*Cicer arietinum*) – Williams and Saxena 1991; cowpea (*Vigna unguiculata*) – Ntare and Williams (in press); and millet (*Pennisetum glaucum*) – ICRISAT 1991], and crop science disciplines.

Crop Physiological Models Applicable to Breeding

From the breeding point of view, crop physiology has failed to provide technologies appropriate to the large numbers of lines in a segregating population. Crop physiology has often sought to identify single factors that apparently condition a process, and have asked the breeders to set out and combine desirable factors. There are only a few cases where this has been more successful than the breeders empiric selection on the final outcome. The isolation of physiological attributes has probably failed because "yield is a complex terminal outcome of growth to which there are diverse and interrelated developmental tracks" (Simmonds 1979, p. 46).

Just as the breeders have accepted models to help explain the phenomena that they are dealing with, crop physiological models are the expression in mathematical terms of the processes determining crop behavior and yield. Crop models have developed along two main paths. Simulation models are intended to estimate the outcome of a set of conditions exploiting existing knowledge of the factors and processes influencing the subject of the model. Analytical models provide a framework for interpretation of results, based on measurement of the interacting parameters. The most widely promoted application of crop models is for **simulation** (e.g., Boote, these Proceedings pp. 331–343; Shorter et al. 1991). This class of model, usually used to provide estimates of yields given hypothetical (or historical) conditions of weather, has some application to breeding programs and will be discussed later.

However, crop models that provide an **analytical** basis for the determination of yield probably have the most scope for immediate application to improve efficiency in a breeding program. Any model appropriate to breeding programs requires that the parameters of the model be obtainable very simply, without additional investments in manual data collection.

Fortunately, several appropriately simple models have been described by Duncan et al. (1978), (Equation 2); and Monteith (1977) (Equations 3 and 4). In using them, we must recognize that these simple models integrate many complex processes into a single parameter. However, while a full understanding of all the processes is desirable, a great deal more can be achieved by working with these 'integrated' parameters than with yield only.

Duncan wrote simulation models for a number of crops, most of which were an expansion of the basic model:

$$Y_R = C * D_R * p \qquad (2)$$

where: Y_R is reproductive yield,
C is the mean crop growth rate,
D_R is the duration of reproductive growth, and
p is the mean fraction of crop growth rate partitioned towards the reproductive organs (Duncan et al. 1978).

In this model C provides a measure of 'source' (an integration of the effects of radiation intercepted by the crop and the photosynthetic result of this). The duration is a relatively simple parameter, while the partitioning parameter provides an integration of the reproductive initiation processes and translocation; p and D_R are terms that describe the 'sink'.

Monteith proposed similarly simple models:

$$Y_R = I * e * H \qquad (3)$$

or

$$Y_T = I * e \qquad (4)$$

where: I is the cumulative radiation (or light) intercepted,
e is the mean rate of assimilation per unit of radiation intercepted,
H is harvest index, and
YT is total biomass.

Model 4 has been found appropriate for many crops (e.g., Gallagher and Biscoe 1978), including groundnuts (Azam Ali et al. 1989). In most species the major source of variations in Y_T are in I rather than e (which is a conservative parameter).

Duncan's model is probably most easily applied to breeding, and the concept of partitioning is better than that of harvest index, particularly in an indeterminate crop such as groundnut. Monteith's models are significant in dealing in more detail with the determinants of crop growth rate than Duncan's model. However, these models can be combined and manipulated, to produce models to address specific requirements.

As stated earlier, many of the problems that the breeder faces can be attributed to the effects of E and $G.E$ dominating those due to G. Physiological models make the interpretation of this variation a much simpler process, thereby allowing material to be evaluated with greater confidence. Conceptually the components of phenotypic yield can be evaluated within the framework of Duncan's model by distributing these sources of variation between the parameters C, p, *and* D_R. No analyses of this type have been done so far but physiological knowledge of the processes permits the probable relative importance of the yield determining factors in one model to the various components of the other to be hypothesized (Table 1).

Crop physiological knowledge suggests that variations in C are dominated by E and $G.E$ because the photosynthetic variation within a species is small, while the scope for variations in energy interception is very large. The evidence concerning partitioning indicates that genotype differences are very much more important in this area; in contrast environment, with some notable exceptions (photoperiod effects in groundnuts; Flohr et al. 1990), is a less significant source of variation in partitioning. It also seems likely that various environmental challenges will have different 'signatures' in influencing C, p, and D_R. For instance, drought will influence C and p, calcium deficiency will influence p, and foliar diseases will mainly influence C.

Table 1. Hypothetical importance (ranked 1 = minor, 9 = major) of parameters in Fisher's model to variation in the parameters of Duncan's model.

Model parameters	G	E	$G.E$
C	1	9	4
p	7	3	5
D_R	5	5	4

Crop Breeding Procedures and Limitations, and their Physiological Basis

Generally, high yield is an important objective in a breeding program, and it is in the achievement of this objective that models may have the greatest amount to offer the breeder. Although the current methods have achieved varieties with high yield potential, each new hybridization effort requires the breeder to reselect for yield. Additionally, for many crop species breeders realize that there is a yield barrier and I believe that the application of Monteith's crop models to selection provides the best chance of advancing further. The removal of variation due to the environmentally determined variations in energy interception will allow direct selection for efficiency of light use if variation exists within the target species.

A breeding program has several phases. These start with identification and choice of objectives, parental materials, and breeding method. This phase is then followed by production of segregating material, selection, and, finally, evaluation of selected lines relative to existing varieties in environments representative of the target cultivation areas.

Identification of objectives

Simulation models may play an important part in a breeding program in defining the objectives (Shorter et al. 1991). For many proposed changes simulation models should be used for sensitivity analysis to determine if (based on the existing knowledge) the outcome will be as anticipated. This could greatly decrease the uncertainty of success. For example, one could vary the phenology controlling parameters of a variety and evaluate the *probable* impact of these changes on yield using historical weather data. This could guide a proposed change in duration to optimize yield and its stability. However, this approach to objective definition requires very expert knowledge of both the model and the crop.

Choice of parental materials and methodology

Both the breeder and physiologist presently invest considerable effort into this phase of variety development. This effort usually involves study of physiological mechanisms contributing to differences in genotypes, and of the modes of inheritance for traits of interest. This knowledge determines how the segregating material is best handled, and how various selection pressures affect the chances of success. Seed yield commonly has low heritability, and this is reflected in the relatively slow progress to high yield potential in most crop species.

Selection for yield and yield potential

Once the breeder has made his crosses and advanced the product for several generations, his interest centers on reducing the numbers of lines to evaluate in better detail.

How reliable is the seed yield of an individual plant growing in a segregating population, or in relative isolation (test row) as a predictor of future yield? Data of plant-to-plant variability in an apparently uniform crop of breeders seed (Williams 1975) suggests that (even for Y_T) single plants in a population are very poor indicators of the pure stand performance, even without the confounding effects of major genetic differences between plants. In terms of Duncan's model this can be most logically explained by variations in C; Monteith's model indicates that this is likely to arise with variation in energy interception, which is determined largely by environment.

Why is it so difficult to select for yield? What is the physiological basis for this low heritability? At present there are no direct data to answer these questions. We have no published data relating to the inheritance of the individual components of Duncan's model. However, it is probable that the p, and D_R will prove to be more highly heritable than yield, while C will prove to be the factor largely responsible for the low inheritance of yield. Evidence to support this suggestion is only circumstantial. In terms of Monteith's model (4) and by assuming a conservative value for e (based on the extent of variation in e observed within most crop species), the basis for large phenotypic variation in Y_T between plants must be large variation in energy interception by individual plants. This view is supported by the evidence that shows that once light interception by a groundnut crop is complete, the major sources of yield variation between varieties lie in their partitioning and duration (Duncan et al. 1978); the progressive increase in pod yield in the Florida groundnut breeding effort was associated with improvements of partitioning, while C remained constant.

Duration of reproductive growth is another important factor that can make direct selection for yield an imprecise exercise. The potential reproductive growth rate (R) of a good groundnut crop is about 100 kg ha^{-1}

d^{-1}, so comparing yield of crops/varieties with even a small difference in D_R can result in poor decisions about the merits of material.

For groundnuts, Y_R alone also may be confounded because of feedback effects due to variation in p that operate in communities of competing plants. In a population of groundnuts with differing p, low yield potential (based on low partitioning) could result in greater plant yield than from high partitioning plants because high partitioning reduces vegetative growth and therefore limits energy interception (i.e., low partitioning plants are more competitive). In a stand of a uniform genotype, the opposite is the logical outcome of these differences in partitioning.

Therefore, selection on yield alone is likely to be misleading. These problems are most commonly catered for (by the breeder) by employing a low selection pressure, which requires that a larger proportion of the material is retained than would otherwise be necessary. However, if the suggested low inheritance of yield is attributable to variations in C and if the processes determining yield can be quantified at this stage, the breeder could appropriately increase the selection pressure for the more genetically controlled parameters (p and D_R). However, in some cases C needs to be considered along with p and D_R because factors, such as foliar disease resistances, will impact mostly on C.

Advanced evaluation

As the breeder reduces the number of genotypes he usually increases the objectivity of his evaluation. He has enough uniform material to test in replicated trials and then to expand these to varied environments. In the final stage of the breeding process the breeder compares the material that has survived his selection process across sites and years to select the most adapted genotypes. At this stage one has to face the possibility that the agronomic practices necessary to maximize the yield of a specific variety may be different from those used as a standard in the evaluation.

Evaluation of trial results using the physiological model determinants of yield rather that yield itself can make clearer the reasons for yield differences, and so guide the further exploitation of material and provide insights that can result in modified screening techniques, and thereby provide more efficient breeding programs. For example, a variety that is failing to yield well in pure stand because of low C is likely to be doing this because of relatively low light interception, and, if it has enough other attributes to recommend it, would justify agronomic manipulation, e.g., higher populations.

Practical Application of Models

To apply these models in a program it is necessary to obtain data for the parameters of the model at the level of the single plant or plot. How can this be done? Traditionally, physiologists have measured the parameters of these crop growth models using destructive growth analysis, a requirement that has prohibited the widespread use of these techniques. However, recent research at ICRISAT has shown that this costly data collection is not necessary for comparative purposes. Only measurements of defoliation percentage, total and pod (or seed) yield at maturity, and phenological observation to fix the start of grain growth and maturity are needed to provide relatively good estimates of C, p, *and* D_R. Observations of radiation interception can refine this data further, but are not essential for many breeding applications. Data for the yield determining parameters can be obtained by two techniques. Firstly, by 'reverse engineering' these simple models one can estimate the parameter C and R that would have resulted in the observed final Y_T and Y_R, (Williams and Saxena 1991). This is most easily done using a linear estimation of growth. However other models, for instance Goudriaan and Monteith's (1990) expolinear model (which would need more advanced "math solver" programs), may provide more accurate estimates of C and R.

Secondly, remotely sensed data for fractional light interception [which may be obtained for groundnuts very cheaply using the differences in reflectance of red and infrared radiation (see Figure 1)] can be combined with incident radiation to estimate the Y_T or C from Monteith's models. Current research at Washington State University, USA, and ICRISAT's Sahelian Center (ISC) is evaluating this second approach. The radiation data can be used to better distribute the accumulated dry matter across time and so improve the estimation of p since Y_T over the reproductive phase can be better estimated.

Partitioning has been traditionally estimated as R+C (Duncan et al. 1978). A comparison of p obtained by 'reverse engineering' with that obtained by conventional growth analysis during the season is presented in Figure 2. The data are from an experiment where photoperiod effects on growth of genotypes were evaluated.

The data on final yield, total biomass, and days to flowering and maturity needed to estimate the para-

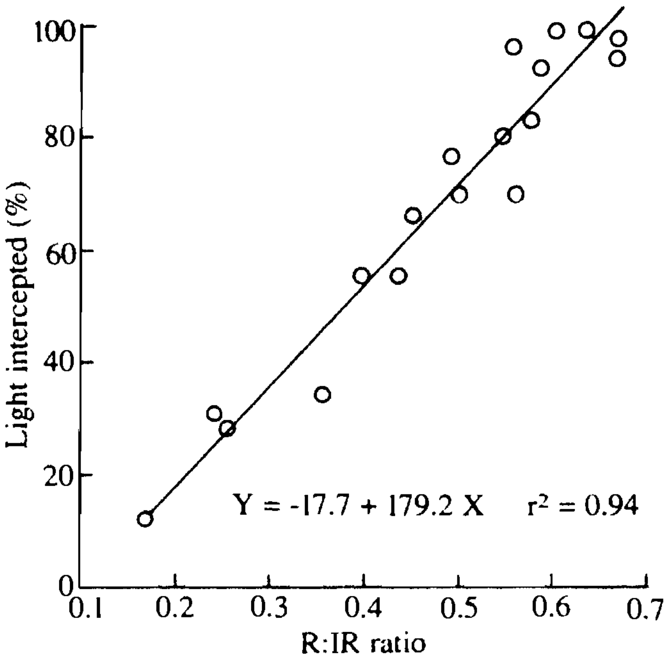


Figure 1. Light interception related to normalized red:infra-red reflectance ratio for groundnuts. (Source: Rao et al. 1992.)

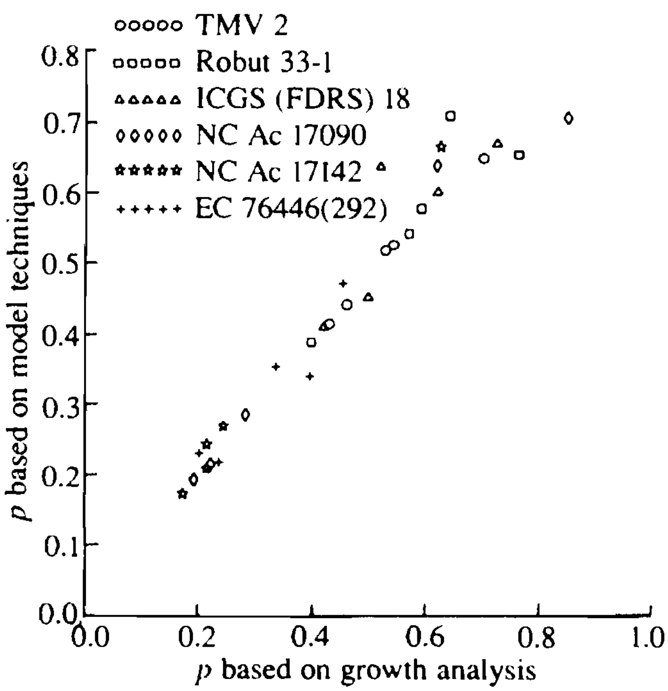


Figure 2. The relationship between partitioning (*p*) estimated directly from growth analysis and partitioning estimated from nondestructive (peripheral) observations. (Source: Unpublished data of Williams, Ramraj, and Devi.)

meters of Duncan's model are mostly already collected by breeders. Only modest computers are needed to do the calculations.

So far no breeding programs have results based on applying these 'model' approaches to selection within segregating populations. However, Greenberg et al. (1990) have shown that all the lines adapted to the Sahelian environment maintained superior p when grown in the very hot summer at ISC with full irrigation. The ISC program is now using nondestructive observations in small plots and these 'model' techniques to estimate partitioning of large numbers of lines. This past season some 625 lines were evaluated in this way.

An Example

Since no results are yet available from selection based on this approach, the best example available is provided by the application of these ideas to the interpretation of data relating to varietal adaptation to Sahelian conditions. The analysis used as an example resulted in the application of these techniques to selection for p at ISC.

The model approach was applied to the data collected in a series of trials comparing genotypes adapted to the Sahelian environment with those from other origins. In the experiments 35 groundnut genotypes were grown in 5 environments where the water (as a fraction of pan evaporation) and temperatures were manipulated by sowing dates and irrigation (Greenberg et al. 1990).

The necessary phenology and final yield data, and the midday canopy temperatures were collected in the summer experiments. After the durations of phases had been converted to thermal time and the weights adjusted for the higher energy values of pods, the parameters of Duncan's model for all 175 treatment combinations were computed. The growth rates (GR) for both C and R were computed as the linear growth rate between sowing and maturity with the standard equation:

$$GR = (Y_2 - Y_1)/(T_2 - T_1).$$

A standard stability analysis (Finley and Wilkinson 1963) was then applied to the determinants of yield (C and p) rather than the yield data. The mean C in each environment ranked according to the fraction of potential evapotranspiration that was satisfied, a result to be expected considering the role of water relations in canopy and leaf area development. However, what was surprising was that the adapted Sahelian varieties were only average for their C in the water deficit environments. Genotypes from other environments had greater C in the water deficit environments (Figure 3a).

Canopy temperature (based on air temperature and air:canopy temperature relationships) varied considerably in the environments, being lowest in the rainy season, intermediate in the hot season with full irrigation and increasing further as the water supply decreased in the hot season. The mean partitioning of the environments increased with lower canopy temperatures. In the normal rainy season all the genotypes had high partitioning, and this declined as the environments became drier and hotter (Figure 3b). However, the Sahelian-adapted genotypes maintained their partitioning at higher levels than nonadapted genotypes in the hotter environments, particularly so in the fully watered summer environment. Thus, tolerance of p to high temperature is apparently more important to groundnut adaptation in the Sahel than superior crop growth rates in the face of limited water.

Conclusion

There is clearly a case to exploit the use of crop physiological models in a breeding program. Simple analytic models may be exploited without major additions to the data gathering exercise that most scientists undertake, and should materially increase the value of the data gathered. The improved information thus available can or may improve the speed of research progress and result in greater satisfaction to the scientists involved.

References

Azam-Ali, S.N., **Simmonds, L.P.**, **Rao, R.C.N.**, and **Williams, J.H.** 1989. Population, growth and water use of groundnut maintained on stored water. 3. Dry matter, water use and light interception. Experimental Agriculture 25:77-86.

Duncan, W.G., **McCloud, D.E.**, **McGraw, R.L.**, and **Boote, K.J.** 1978. Physiological aspects of peanut yield improvement. Crop Science 18:1015-1020.

Finley, K.W., and **Wilkinson, G.N.** 1963. The analysis of adaptation in a plant-breeding program. Australian Journal of Agricultural Research 14:742-754.

Fisher, R.A. 1926. The arrangement of field experiments. Journal of Ministry of Agriculture 33:503-513.

Flohr, M, **Williams, J.H.**, and **Lenz, F.** 1990. The effect of photoperiod on the reproductive development of a photoperiod sensitive groundnut (*Arachis*

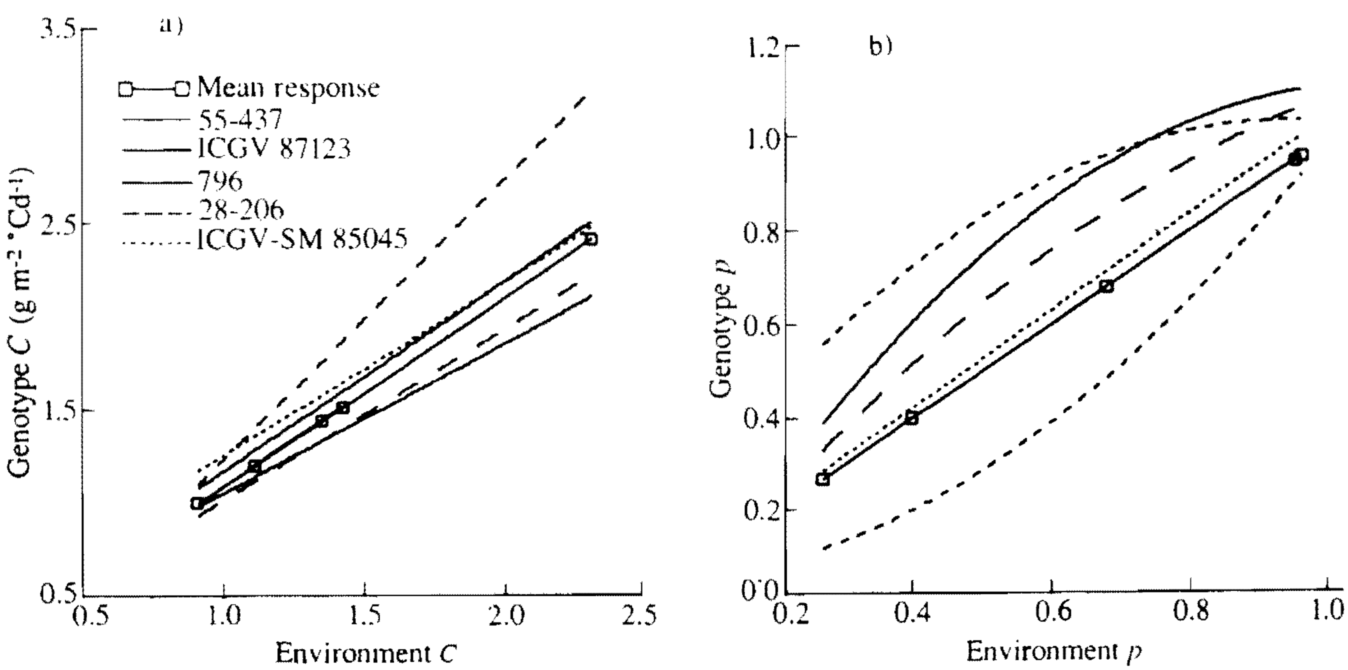


Figure 3. Stability of mean crop growth rate (C) and partitioning (p) for genotypes adapted and non-adapted to Sahelian conditions exposed to environments with varied water supply and temperature conditions.

hypogaea L.) Cv NC Ac 17090. Experimental Agriculture 26:397-406.

Gallagher, J.N., and **Biscoe, P.V.** 1978. Radiation absorption, growth and yield of cereals. Journal of Agricultural Science (UK) 91:47-60.

Goudriaan, J., and **Monteith, J.L.** 1990. A mathematical function for crop growth based on light interception and leaf area expansion. Annals of Botany 66:695-701.

Greenberg, D.C., Williams, J.H., Waliar, F., and **Ndunguru, B.J.** 1990. Drought effects on growth and *Aspergillus* infestation of groundnut cultivars in West Africa. Pages 71-81 *in* proceedings of the Fourth Regional Groundnut Workshop for Southern Africa, 19-23 Mar 1990, Arusha, Tanzania. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1991. ICRISAT West African programs report 1990. Niamey, Niger: ICRISAT, Sahelian Center.

Monteith, J.L. 1977. Climate and the efficiency of crop production in Britain. Philosophical Transactions of the Royal Society of London, B 281:277.

Ntare, B.R., and **Williams, J.H.** (In press.) Selection of cowpea cultivars for cool season production in the Sahel. Field Crops Research.

Pixley, K.V., Boote, K.J., Shokes, F.M., and **Gorbet, D.W.** 1990. Growth and partitioning characteristics of four peanut genotypes differing in resistance to late leaf spot. Crop Science 30:796-804.

Rao, R.C.N., Williams, J.H., Rao, M., and **Wadia, K.D.R.** 1992. A red-infrared reflectometer for measuring radiation interception by crop canopies. Field Crops Research 29:353-360.

Shorter, R., Lawn, R.J., and **Hammer, G.L.** 1991. Improving genotypic adaptation in crops – a role for breeders, physiologists and modellers. Experimental Agriculture 27:155-175.

Simmonds, N.W. 1979. Principles of crop improvement. London, UK: Longman.

Williams J.H. 1975. A study of some of the factors influencing development and yield of groundnuts *(Arachis hypogaea* L.) with special reference to the distribution of dry mass. M. Phil. thesis, University of Zimbabwe, Harare, Zimbabwe.

Williams, J.H., and **Saxena, N.P.** 1991. The use of non-destructive measurement and physiological models of yield determination to investigate factors determining differences in seed yield between genotypes of "desi" chickpeas (*Cicer arietinum*). Annals of Applied Biology 119:105-112.

Discussion

Ramana Rao: Under water stress, the effective leaf area index (LAI) of groundnut is different than the measured LAI because leaf orientation changes with water stress. Therefore, the predicted light interception will be different and hence the estimates of crop growth.

K.J. Boote: I agree with your observation, but do not think that it will have a significant effect on growth estimates. However, changes can be made in the model to simulate this phenomenon.

M.V.R. Prasad: Based on the information you have, could you suggest some reliable and stable criteria of selection for breeding for higher productivity? The traditional criteria employed, pod yield, is very unstable.

J.H. Williams: Estimates of crop growth rate and measurement of partitioning would be better in my opinion.

P.W. Amin: Are spanish groundnuts more effective in partitioning than virginia types?

J.H. Williams: It cannot be generalized. It depends on the genotype within the group.

Z.A. Chiteka: Is there any simple method to estimate partitioning in groundnut?

J.H. Williams: We just need to measure date of flowering, date of maturity, pod yield, and biomass at harvest, including accounting for leaf loss, to determine partitioning in groundnut.

Networks, Working Groups, and Their Role in Enhancing Collaborative Research in Groundnut

D.G. Faris, C.L.L. Gowda, and D.V.R. Reddy[1]

Abstract

Agricultural research networks are tools for strengthening agricultural research in developing countries by using existing facilities and staff more effectively. This tool avoids duplication of effort and can make available a critical mass of research effort to solve specific problems at a relatively low cost.

This paper briefly reviews how networks are organized and operate; how scientists in national programs can strengthen their personal scientific capabilities and upgrade their research; what pitfalls National Agricultural Research System (NARS) administrators must consider in becoming involved; and the ways in which International Agricultural Research Centers (IARCs) use networks to expand their information bases and share their material and information with NARSs.

*It then outlines the organization of the Asian Grain Legumes Network (AGLN) and other networks facilitating collaborative research on groundnut (*Arachis hypogaea*). Finally it examines the concept of Working Groups and how they are being used by the AGLN to focus and strengthen collaborative research on groundnut.*

Résumé

Réseaux, groupes de travail et leur rôle pour le financement de recherche en collaboration sur l'arachide: *Les réseaux de recherches agricoles sont des outils pour renforcer la recherche agricole dans les pays en développement en utilisant plus efficacement les moyens d'action existants et le personnel. Cet outil évite les doublements d'efforts et peut fournir une masse critique d'efforts de recherches pour résoudre des problèmes spécifiques à un coût relativement modéré.*

Cette communication examine brièvement comment les réseaux sont organisés et fonctionnent; comment les scientifiques des programmes nationaux peuvent renforcer leurs potentiels scientifiques personnels et promouvoir leurs recherches; quels pièges les administrateurs d'un Système national de recherche agricole doivent risquer de subir; et les manières dont les centres internationaux de recherche agricole emploient des réseaux pour élargir leurs bases d'information et partager leur matériel et l'information avec les Systèmes nationaux.

*Ensuite, la communication décrit brièvement l'organisation du réseau asiatique des légumineuses à grain (AGLN) et d'autres réseaux qui facilitent la recherche en collaboration sur l'arachide (*Arachis hypogaea*). Finalement elle examine le concept des groupes de travail et comment ils servent à l'AGLN pour concentrer et renforcer la recherche en collaboration sur l'arachide.*

---

1. Principal Coordinator, Asian Grain Legumes Network (AGLN), Senior Plant Breeder, and Principal Plant Virologist, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, A.P. 502 324, India.

ICRISAT Conference Paper no. CP 808.

Faris, D.G., Gowda, C.L.L., and **Reddy, D.V.R.** 1992. Networks, working groups, and their role in enhancing collaborative research in groundnut. Pages 355–363 *in* Groundnut – a global perspective: proceedings of an international workshop, 25–29 Nov 1991, ICRISAT Center, India (Nigam, S.N., ed.). Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Networks and networking are increasingly attracting attention as a means for using facilities and staff more effectively. This approach is used to avoid duplication of effort and to engage, at relatively low cost, a critical mass of personnel in research to solve specific problems. Networking is a tool to strengthen agricultural research in developed and developing countries. International donors and many others see the value of agricultural research networks but want to know what are the elements for success, and the hazards to be avoided.

Definition

A general definition of agricultural networks is difficult because of their diversity of purposes, forms, and operations. A simple definition that takes in all forms of agricultural networks is as follows (Faris 1991):

A Collaborative Agricultural Research Network (CARNET) is a group of individuals or institutions linked together because of commitment to collaborate in solving a common agricultural problem or a set of problems and to use existing resources more effectively.

Objectives

The following network objectives were developed by a group of network coordinators in Nairobi, Kenya in 1988 (Faris and Ker 1988) to:

- Strengthen the applied research capability of National Agricultural Research Systems (NARSs) to identify, address, and solve farmers' problems;
- Generate appropriate technology by using existing research personnel, facilities, and other resources more effectively;
- Ensure stability of agricultural production through a responsive research capability; and
- Provide the support, both technical and financial, needed to facilitate the coordination of activities on a regional basis.

Network Types

Networks vary widely and are dynamic, making classification difficult. A standard classification provided by Ralph Cummins Jr. and Calvin Martin (SPAAR 1987a, 1987b) classifies networks into three types:

- Type I – Information Exchange Network facilitates simple exchange of ideas, methodologies, and research results usually through a Coordination Unit.
- Type II – Scientific Consultation Network allows individuals or groups to focus on a common problem, conduct their research independently, and share their results at common meetings.
- Type III – Collaborative Research Network provides joint planning and monitoring of a common research problem, and it includes elements of the first two types.

Collaborative research networks can be further subdivided on the basis of their general approach: international nurseries networks; methodology networks (the Asian Rice Farming Systems Network is an example); regional program networks [the SADCC (South African Development Coordination Conference)/ICRISAT program is an example]; and NARS-based networks [the Regional Cooperative Potato Research Program for Central America and the Caribbean (PRECODEPA) is an example].

CARNET components

The components of a successful network are research, coordination, communication, membership, and assets (Faris 1991).

Research is the component around which collaborative agricultural research networks (CARNETs) are organized. This component includes information and literature; research per se, conducted by network members; the products of research, such as new technologies or crop varieties; methods; socioeconomic analyses; and databases and their management. How these activities are dealt with in CARNETs is a key to the merits and weaknesses of networks in strengthening research initiatives.

A strong coordination unit is needed to effectively organize and harmonize network activities. This unit is usually comprised of a coordinator and one or more steering groups that represent the members' needs and wishes, and guide and direct the activities of the coordinator. The coordination unit plays a vital role but represents a major expense associated with networks.

The communications component enables the interchange of information and material through correspondence, telecommunications, visits, meetings, workshops, training, and publications. Many of these activities usually require special funding.

The membership component is the body of a CARNET; members produce and draw on the networks' databases. Members can be scientists or administrators from national and international programs, from developed countries, and from donor groups. In some networks, whole projects, institutions, or NARSs are considered members. All members should feel that the network and its activities are designed for them personally.

Assets of a network include members and the facilities and resources available to its members plus external finances to support its activities. This component derives value from other components and is an integral part of them.

Network structures

Network structures can be represented graphically to show how their components are linked and how they interact, to elucidate their functioning and dynamics, and to suggest elements that encourage success. Depictions or models can also help clarify differences among networks.

A simple wheel-like model is the classical depiction of networks (Faris 1991). The 'hub' represents the coordination unit, which is connected to network 'nodes' through 'spokes' (Fig. 1a). The spokes represent the communication component, and the nodes the membership component. A node may be an individual, a research project, an institute, or a NARS. In a simple information-sharing network, movement can be one-way from the hub to the node, but, for example, in a material-exchange network, movement is two-way. If the network also includes communication directly between nodes, through such devices as workshops, monitoring tours, and correspondence, then the network is seen as having a 'rim' (Fig. 1b). The rim is also part of the communication component. All networks that plan jointly have a rim. In most collaborative agricultural research networks, the nodes are also hubs with spokes to cooperative research units (Fig. 1c).

Other presentations of network structures have been used but none truly represents the dynamic and constantly changing character of networks. Like a living organism, a network is conceived, born, grows, and develops, learning from mistakes and from experiences of similar organisms. The network members form the body of the organism, providing the bulk and muscle power, carrying out network activities. The research component is like the metabolism, yielding life, energy, and products that the blood circulates. The heart and blood vessels, along with the nerves (the coordination component), together form the communication component. The assets component – consisting of national and international facilities and human as well as financial resources – is like food that provides the energy that keeps the whole organism active. The analogy ends there but serves the purpose of illustrating the interdependency of network components. It also illustrates why networks should develop all components together.

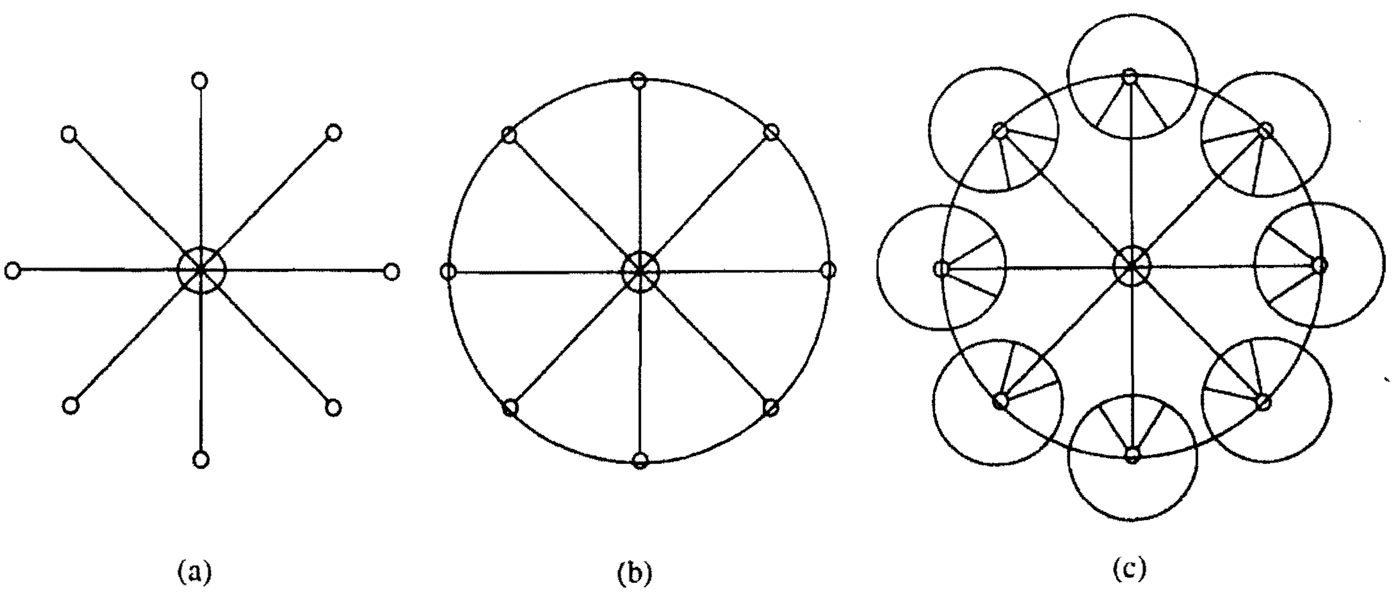


Figure 1. A wheel-like depiction of networks, showing the coordinating hub in the center, the spokes linking the nodes (a), the rim joining the nodes (b), and the nodes forming research units or subnetworks (c).

Costs and Benefits

Networks are not a panacea; there are costs, and there can be problems. From the perspectives of different participants in a network, a benefit to one may be a cost to another.

Networks benefit NARSs both by strengthening the research program associated with the network and by improving members' ability to do research in other programs. In networks, NARS programs become part of the critical mass needed to provide breakthroughs. In general, networks do not build facilities specifically for their activities nor do they employ many permanent staff; thus, they can change research directions easily as new, more important problems are identified by participants. Network activities, such as workshops, give NARS scientists a chance to share ideas and results, interact with international experts, and broaden their outlook.

International Agricultural Research Centers (IARCs) see networks as an ideal means to solidify their partnerships with national scientists, and to channel technology to NARSs for use by farmers. Networks also directly benefit the IARCs' research programs by providing a way to test material under a wide range of conditions and by encouraging feedback from NARSs, national scientists, and farmers.

Donors see networks as an aid in allocating their funds to identified high-priority problems, directing assistance to specific, well-organized targets, and reducing duplication.

The costs of achieving these benefits are not only the expenditure of funds, time, and effort but also the problems and losses that at times result from NARSs involvement in networks. When NARSs participate in networks, they relinquish some control over their research agenda and may even have to dedicate key researchers to work that does not address the NARS's priorities. NARSs should, therefore, carefully consider and choose the networks in which they become involved and not be enticed by donors to join inappropriate networks.

Normally, network research activities are funded by NARSs, either from their operational budgets or from special bilateral projects. In some cases, NARSs do not have adequate funds, and progress of research in the network is hindered. To overcome this problem, donors often set aside small sums for network coordinators to give to network members to ensure continuity in the research.

IARCs normally provide network coordination and scientific backstopping; the costs of these activities are often covered by special funds from donor agencies.

In some cases, networks have fulfilled the role that an IARC would play. For example, in West Africa, networking among francophone countries has received support from France in preference to setting up an international research center in the region, e.g., the Conférence des résponsables africains et français de la recherche agronomique (CORAF) (see Workshop Recommendations.for details).

Traits of Successful Networks

Reasons for success and failure of networks are not always clear. Interpersonal dynamics in a network are complicated, and one person's definition of success may differ markedly from another's. General reviews of networks almost invariably include a consideration of the characteristics of successful ones. Faris (1991) examined the traits identified by 23 authors and classified them by network component (research, coordination, communication, members, and assets) (Table 1).

Networks and global groundnut (*Arachis hypogaea*) research

We would now like to review the role of networks in furthering global groundnut research. Collaborative research activities similar to CARNETs were originally conducted by colonial government research organizations, mostly to improve the production of export crops; groundnut was one of these. Interinstitute and interuniversity collaborative research in many countries are essentially networks. The All India Coordinated Research Project on Oilseeds, supported by the Indian Council of Agricultural Research, is a good example. Groundnut scientists in India meet twice a year to review previous results, identify new research areas, prepare research plans, and allocate responsibilities to appropriate research centers. Similar research coordination can be found in many other countries: the Instituto Nacional de Investigaciones Forestales y Agropecuarias (INIFAP) in Mexico and the Philippine Council for Agriculture and Resources Research and Development (PCARRD) in the Philippines are examples (Faris 1991). Now much of the research on groundnut is conducted in formal or informal networks. Most IARCs and donors such as the United Nations Development Programme (UNDP), the Food and Agriculture Organization of the United Nations (FAO), the United States Agency for International Development

Table 1. Traits of five network components considered important for a successful CARNET (based on the number of times the trait was identified in 23 publications).

Network component	Trait	Times identified
Research	A well-defined common theme or strategy	14
	An important, widely shared objective or problem	10
	An existing or potential source of improved technology (research)	8
	A realistic research agenda	3
Coordination	Strong and effective coordination	13
	A steering committee or advisory group	6
Communication	Education and training	8
	Regular meetings (workshops)	4
	Information-exchange system	4
	Free exchange of results, methods, materials, ideas, and participants	2
Members	Commitment of funds, resources, and staff by NARSs	9
	Strong self-interest served	7
	Capacity to contribute	6
	Participants involved in network management	3
Assets	Flexible outside funding	11

Source: Faris 1991.

(USAID), and the International Development Research Centre (IDRC), Canada, have supported networking to avoid duplication of NARS efforts.

Some other formal groups and networks that address collaborative groundnut research are described below.

Asian Grain Legumes Network (AGLN)

The Asian Grain Legumes Network (AGLN) was established in 1986 to fill a need identified by national programs in Asia. The network facilitates interchange of material, technology, and information on chickpea (*Cicer arietinum*), groundnut, and pigeonpea (*Cajanus cajan*) among scientists in Asia with the aim of assisting farmers in the region increase their production of these legumes.

AGLN's membership includes ICRISAT scientists. It also includes scientists, administrators, and extension specialists in NARS, in regional and international institutions in Asia, and in advanced research institutes in other countries interested in research on AGLN crops. The network has formal collaboration with 11 countries in Asia (Bangladesh, People's Republic of China, India, Indonesia, Myanmar, Nepal, Pakistan, Philippines, Sri Lanka, Thailand, and Vietnam). It works with other countries of Asia when assistance is requested. Presently ICRISAT provides the AGLN Coordination Unit (CU).

AGLN's structure has bilateral and multilateral elements. The bilateral element is built on strong links between ICRISAT and NARS scientists based on formal Memoranda of Understanding (MOUs) between each NARS and ICRISAT, and on collaborative work plans giving details of agreed research and commitments by NARS and ICRISAT. The AGLN country coordinator provides the administrative link with the CU at ICRISAT. AGLN also has bilateral links with donors, and international, regional, and mentor institutions.

The multilateral element is provided by the many network activities that bring AGLN members together, such as coordinators' meetings, workshops, monitoring tours, scientists' meetings, training courses, and working groups.

Conférence des résponsables africains et française de la recherche agronomique (CORAF)

CORAF was organized in 1986 for research and technical cooperation among francophone countries in Africa. CORAF has a series of subnetworks covering maize (*Zea mays*), rice (*Oryza sativa*), cassava (*Mani-*

hot esculenta), groundnut, and drought resistance (Schilling 1988). The main objectives of CORAF subnetworks are to:

- Facilitate the development of African NARS and give them a regional or international dimension;
- Provide the conditions for cooperation among regional and international organizations; and
- Identify high priority research needs, within the terms of each network, for support by international sponsors.

CORAF's groundnut subnetwork assembly has one member from each cooperating country and ICRISAT's Sahelian Center as an observer. The assembly is supported by a full time secretariat for coordination. The network is coordinated by the Institut senegalais de recherches agricoles (ISRA) of Senegal in collaboration with the Institut de recherches pour les huiles et oleagineux (IRHO), France.

The Peanut Collaborative Research Support Program (CRSP)

The Peanut CRSP brings together resources of developing countries and U.S. research institutions aimed at increasing production and utilization of groundnut in developing countries. It is funded through the "Title XII – Famine Prevention and Freedom from Hunger" of the United States Congress, and was implemented on 1 July 1982 (Cummins 1984). The basic objectives are to:

- Conduct research to relieve constraints to groundnut production and utilization,
- Provide short-term and degree-training programs for host country staff,
- Provide consultancy and program support for equipment supplies and travel, and
- Exchange germplasm, and knowledge of production and utilization.

The project involves four U.S. universities (Alabama A&M, Georgia, North Carolina State, and Texas A&M), and nine countries (Thailand, Philippines, Senegal, Mali, Burkina Faso, Niger, Nigeria, Sudan, and Trinidad). Individual projects are designed around priorities and constraints in host countries, but also focus on regional research and development priorities. Information derived from projects is shared with others regionally and globally through reports, publications, meetings, and workshops.

Some examples are co-publication of the *International Arachis Newsletter*, publication of Field diagnosis of groundnut diseases, ICRISAT Information Bulletin no. 36, and support to virus research in the Working Group on Asia-Pacific Groundnut Viruses.

Working Groups

Working Groups are essentially mini-networks formed by a group of specialists committed to work together to address high priority regional problems. Working Groups effectively use experts from advanced laboratories in developing and developed countries. These highly qualified scientists can share components of research that need to be done and can form the critical mass needed to quickly find answers to specific problems. As in networks, working groups use existing staff and facilities to work together at a high level of expertise and avoid duplication. Organization and financial support for these working groups are similar to those for networks.

These working groups resemble the 'Research Consortium' approach of the International Rice Research Institute (IRRI). Those NARSs and institutes that have comparative advantage serve as 'lead centers' or 'satellite centers' to undertake research as agreed in the working group meetings, and share their research findings with others.

Advantages

Organizing Working Groups (WG) to carry out collaborative research within a network like the AGLN have several advantages:

- WGs specialize in tackling and quickly solving high priority problems important to the network members.
- WGs provide a series of discrete entities under the network that can be started and terminated as problems are identified and solved.
- The small size of a WG makes it relatively cheap and easy to get its members together.
- WG meetings can be very productive as they are tightly focused.
- Funding research and training activities within one WG can help support overlapping activities of another group, for example, laboratory and field facilities, travel, training courses, and meetings.
- The main network and its Coordination Unit can

facilitate the WG's activities by providing administrative coordination and logistical support.

- The members of the main network can continuously help to identify problems that need solutions.
- The network organization can be used to quickly disseminate research results and other information to WG members.

Organization

Each WG has a Technical Coordinator (TC) to coordinate the research activities of the group. The TC is identified by the WG members and follows their directions. The TC is an expert in the subject of the WG working at the lead center for the WG topic.

Membership will include scientists from NARSs, international and regional institutes, and laboratories in developed countries who are experts in the topic of the WG.

Logistical coordination is provided by the main network's Coordination Unit.

The following working groups are examples of how the approach can be utilized to find solutions to regional groundnut problems.

Working Group on Groundnut Rosette Disease

Groundnut rosette is the most important groundnut virus disease in Africa. It often occurs in epidemic proportions and causes millions of dollars of crop loss. Since the first report of its occurrence in 1905, research on rosette has been restricted to distinguishing various types of rosette, transmission by aphids (*Aphis craccivora*), and management of the disease culturally and by insecticide application.

Resistance to rosette was identified in groundnut landraces from Côte d'Ivoire and Burkina Faso, and used in breeding programs in Senegal, Nigeria, and Malawi. These cultivars have maintained their resistance for over 25 years.

Despite the progress made on managing rosette disease, very little was known about the causal viruses prior to 1983. To detect and characterize the virus, access to advanced technology was essential. It was apparent that this research would have to be done in a country where groundnuts are not grown but where good virology research facilities were available. Thus cooperative links were established in 1981 with virologists in the Institute for Plant Protection in Brunswick (BBA), West Germany, and in 1983 with the Scottish Crop Research Institute (SCRI), Invergowrie, UK. The Peanut CRSP initiated a project on identification of groundnut viruses in West Africa in 1982. The Peanut CRSP organized the first meeting among these groups to discuss coordination of research on rosette disease. Despite significant progress as a result of this meeting there was still the need for more coordination. Therefore, ICRISAT organized a second meeting of the Working Group in the UK in 1985. All the research groups involved including African NARSs were present. ICRISAT and the Peanut CRSP were given the responsibility of technical coordination and each group was given a specific aspect of the problem related to rosette.

The Working Group met again in 1987 (ICRISAT 1988a) and in 1990, when the Group's scope was widened to include other economically important groundnut viruses and the membership was increased to include more African NARSs. The efforts of this Working Group has resulted in substantial progress on the causal viruses of rosette disease, providing the technology to answer farmers problems.

It was found that a satellite RNA, which depends on groundnut rosette virus (GRV) RNA caused the symptoms of rosette disease. GRV can replicate in groundnut plants without the production of overt symptoms. Both GRV and the satellite depend on the packaging of their RNA in the coat protein of a second virus, the groundnut rosette assistor virus (GRAV) for transmission by the aphid vector. Thus, for spread of groundnut rosette disease all three agents (GRAV, GRV, and its satellite) are necessary. Attacking any one or all of them should provide a means to control the disease. As a result of these findings it is now possible to study components and mechanisms of resistance.

Asia-Pacific Working Group on Groundnut Viruses

This Working Group started as the peanut stripe virus (PStV) working group in 1987. Peanut stripe is an important disease in the People's Republic of China, Indonesia, the Philippines, Malaysia, and Thailand, and has become established in the USA. Its appearance and establishment as a major disease in the USA through seed imported from the People's Republic of China underscores its significant threat to other groundnut growing countries. A PStV researchers consultative meeting was organized by AGLN/ICRISAT [in collaboration with the Australian Centre for International Agricultural Research (ACIAR), the Peanut CRSP, and AARD, Indonesia] in Indonesia in

1987 (ICRISAT 1988b). The objective was to bring together all information on the disease, review research, identify future needs, and prepare a plan of action to manage the disease. Twenty participants from eight countries, ACIAR, FAO, and the Peanut CRSP participated. Nomenclature of the disease, which was earlier confused with peanut mottle, was clarified and agreed upon. Participants recommended that future research should be coordinated by AGLN, and identified scientists in each country to lead PStV research. Salient features of research conducted by the working group are:

- Publication of the nomenclature of the disease to avoid confusion.
- About 10 000 groundnut germplasm lines, wild *Arachis* species, and interspecific derivatives have been screened under field conditions in Indonesia. None of the germplasm shows resistance. A few tolerant, late infection lines have been identified, some of which are interspecific cross derivatives. *Arachis duranensis* was found to be resistant. Some lines have low seed transmission.
- A Thai scientist with support from IDRC worked at Montpellier, France, to characterize the isolates of PStV and prepare antisera for their identification.
- Studies in Indonesia have indicated that yield losses due to PStV are 40–50% if infection occurs early in the crop growth, 1–3 weeks after emergence, especially in the dry season.
- Two regional training courses at Malang, Indonesia, and ICRISAT and one in-country course in the People's Republic of China have been conducted to teach methods for identifying PStV and other groundnut viruses.
- A second consultative group meeting was held at ICRISAT Center in August 1991 to review results since the 1987 meeting and plan future research (ICRISAT 1989). The participants made several recommendations with regard to detection and identification of viruses (seed movement and quarantine); epidemiology (vectors, transmission, yield-loss studies, and surveys); groundnut viruses and their control; and regional activities. They also decided to expand the group to include several scientists working outside the region, and renamed the group the "Working Group on Asia-Pacific Groundnut Viruses". The AGLN was asked to continue coordination for the working group.

The establishment of this working group has helped focus attention on PStV and other viruses and ensure that support is provided for research.

Working Group on Bacterial Wilt (*Pseudomonas solanacearum*) of Groundnut

Bacterial wilt of groundnut caused by *Pseudomonas solanacearum* is a major disease in the People's Republic of China, Indonesia, Malaysia, the Philippines, and Thailand in Asia, and in Uganda in Africa. Yield losses are reported to vary from 20–50% depending on the incidence and occurrence of the disease. Research efforts have been isolated and discontinuous. Most results from the People's Republic of China were not available to others; and Chinese scientists could not interact with other scientists. A joint ACIAR/ICRISAT Collaborative Research Planning Meeting on Bacterial Wilt of Groundnut was held in Mar 1990 in Malaysia. Twenty-nine scientists from Australia, the People's Republic of China, Indonesia, Malaysia, Nepal, Philippines, Sri Lanka, Thailand, the UK, the USA, ACIAR, the Asian Vegetable Research and Development Center (AVRDC), and ICRISAT participated (Middleton and Hayward 1990). Following a review of past results the participants recommended coordination of research on bacterial wilt, and listed the following lines of research: characterization of *Pseudomonas solanacearum*, host range and strain differentiation, epidemiology and survival, detection of latent infection and seed transmission, and host plant resistance. AGLN/ICRISAT was requested to be Administrative Coordinator, and Dr A.C. Hayward, University of Queensland, Australia was nominated as the Technical Coordinator.

Working Group on Integrated Pest Management (IPM) and Insecticide Resistance Management (IRM) in Legume Crops in Asia

This working group addresses IPM and IRM for legumes, especially chickpea, pigeonpea, and groundnut in Asia. Legume crops are particularly susceptible to a wide range of pests. Injudicious use of pesticides often leads to massive pest resurgences that are attributed to disruption of natural control processes and the development of insecticide resistance. Yet alternative strategies to total reliance on insecticides do exist. Some of these strategies may not be fully understood by all plant protectionists in the region. This working group was, therefore, mooted to allow exchange of information, coordinate research, and help those concerned with IPM in legume crops to focus on the requirements of farmers. A consultative group meeting of representatives of NARSs, IARCs, the agrochemical industry, and the commercial grain legume growing sector was held in March 1991 in Thailand (ICRISAT 1991). The participants agreed to form a subnetwork (working group) to support IPM and IRM, and disseminate information.

Other Working Groups

Apart from those described above, there are other research areas that are of regional interest. The following are potential working groups for groundnut in the future:

- Acid soil tolerance Working Group,
- Working group on Aflatoxin contamination in groundnut,
- Working group on stem rot/pod rot in groundnut,
- Working group on agroclimatology of AGLN crops in Asia,
- Nematology working group,
- Drought resistance working group,
- Working group on nitrogen nutrition of legumes,
- Working group on utilization of legumes, and
- Working group on small equipment for groundnut production.

These could be initiated as and when enough scientists and/or institutions show interest and are willing to pool staff, expertise, and resources to tackle the issues in a coordinated manner.

References

Cummins, D.G. 1984. The Peanut Collaborative Research Support Program. Pages 92–94 *in* Grain legumes in Asia: summary proceedings of the Consultative Group Meeting for Asian Regional Research on Grain Legumes (Groundnut, Chickpea, Pigeonpea), 11-15 Dec 1983, ICRISAT Center, India. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Faris, D.G. 1991. Agricultural research networks as development tools: views of a network coordinator. Ottawa, Canada: International Development Research Centre, and Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Faris, D.G., and **Ker, A.D.R.** (eds.) 1988. Eastern and southern Africa network coordinators' review: proceedings of a workshop held at Nairobi, Kenya, 9-12 May 1988. Ottawa, Canada: International Development Research Centre. 100 pp.

ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1988a. Coordinated research on groundnut rosette virus disease: summary proceedings of the Consultative Group Meeting, 8-10 Mar 1987, Lilongwe, Malawi. Patancheru, A.P. 502 324, India: ICRISAT.

ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1988b. Coordination of research on peanut stripe virus: summary proceedings of the First Meeting to Coordinate Research on Peanut Stripe Virus Disease of Groundnut, 9-12 Jun 1987, Malang, Indonesia. Patancheru, A.P. 502 324, India: ICRISAT.

ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1989. Summary proceedings of the Second Coordinators' Meeting on Peanut Stripe Virus, 1-4 Aug 1989, ICRISAT Center, India. Patancheru, A.P. 502 324, India: ICRISAT.

ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1991. Summary and recommendations of the Workshop on Integrated Pest Management and Insecticide Resistance Management in Legume Crops in Asia, 19-22 Mar 1991, Chiang Mai, Thailand. Patancheru, A.P. 502 324, India: ICRISAT.

Middleton, K.J., and **Hayward, A.C.** (eds.) 1990. Bacterial wilt of groundnut: proceedings of an ACIAR/ICRISAT Collaborative Research Planning Meeting, 18-19 Mar 1990, Genting Highlands, Malaysia. Proceedings no. 31. Canberra, Australia: Australian Centre for International Agricultural Research.

Schilling, R. 1988. Reseau franco-africain de recherches sur làrachide: note de présentation. (In Fr.) Arachide Infos 1:3-11.

SPAAR (Special Program for African Agricultural Research). 1987a. The Special Program for African Agricultural Research (SPAAR): its objectives and activities. Washington D.C., USA: SPAAR. 7 pp.

SPAAR (Special Program for African Agricultural Research). 1987b. Collaborative research networks: desirable characteristics. Washington D.C., USA: SPAAR. 5 pp.

Discussion

P.W. Amin:

1. We envisage that once we train certain NARSs scientists they should be helping other weaker NARSs wherever the problem exists. Is this occurring?
2. In the working groups – farming systems should be included. Otherwise too many crop based networks may operate in-country which may over burden NARSs.
3. Your objective "to stabilize production" is a complicated one as production depends on not only biotic/abiotic stresses, but mainly on Government policies and the socioeconomic environment.

D.G. Faris:

1. NARSs scientists have participated in training, e.g., China using staff trained at ICRISAT for incountry training, which proved valuable. Scientists from Indian national program have also served on faculty of many training courses. Inter-NARSs working is at the planning stage.
2. The working group on farming systems is important and should be considered by the workshop. Care will be taken to ensure that working groups will not place a load on NARSs scientists.
3. Efforts of AGLN are directed towards a stable production system, not necessarily highest production. Using locally available inputs and appropriate technology, we are concerned with the stability of production systems.

N.K. Sanghi: With respect to working groups, more emphasis should be given to groups for diagnostic surveys which should work in the villages where the problems are and should include farmers in them. Field problems requiring group action, e.g., pest management, should include NGOs in the working group.

D.G. Faris: Constraint identification is an important activity which includes interaction with farmers. However, NARSs need to address this issue because some of these problems are site specific and ICRISAT's role is limited in this regard mainly to developing methodologies with the NARSs. In some cases NGOs were contacted and their involvement was found useful.

Breeding for Eating Quality of Groundnut in Japan

H. Gocho[1]

Abstract

*In Japan the eating quality of groundnut (*Arachis hypogaea*) is a very important character as groundnut is used as a delicacy. Smaller, sweeter, and harder seeds of groundnut showed a better eating quality than larger, less sweet, and less hard ones. External quality of seed was not correlated with eating quality. Seed hardness and sucrose content decreased with the delay in harvesting time. Comparison of seed hardness determined by sensory testing with that by mechanical testing revealed that selection for seed hardness could be achieved by mechanical testing when the seed water content remained in the range of 5–9% at 85 days after flowering. Analysis of sucrose content for selection should be performed 75 days after flowering in the early-maturing group, 80–85 days in the medium-maturing group, and 95 days in the late-maturing group.*

Résumé

Sélection des qualités gustatives de l'arachide au Japon: *Au Japon, la qualité gustative de l'arachide (*Arachis hypogaea*) est une caractéristique très importante, car l'arachide est un produit de confiserie. Des graines, plus petites, plus douces et plus dures d'arachide ont une qualité de bouche meilleure que les graines plus grandes, moins douces et moins dures. La qualité externe des graines ne présentait pas de corrélation avec la qualité de dégustation. La dureté des graines et leur teneur en sucrose diminuaient lorsque la récolte était retardée. La détermination de la dureté des graines par test sensoriel en comparaison avec le test mécanique, révélait que la sélection pour la dureté des graines pourrait être effectuée par un test mécanique lorsque la teneur en eau des graines demeurait dans la gamme des 5–9% à 85 jours après la floraison. L'analyse de la teneur en sucrose pour la sélection doit être effectuée 75 jours après la floraison dans le groupe à cycle précoce, 80–85 jours dans le groupe à cycle moyen et 95 jours dans le groupe à cycle tardif.*

Groundnut (*Arachis hypogaea*) consumption in Japan amounted to 85 000 t in 1989, of which only 44% was produced in the country. In Japan groundnut is a minor crop and is grown on about 19 000 ha. The main center of production is the Kanto region, which is situated in the central part of the country. In this region, groundnut production amounts to 85% of the total production in the country. Therefore, in the Kanto region groundnut is an important upland crop. The main cultivation area in Japan consists of light volcanic soil or sandy soil. A large amount of farmyard manure and chemical fertilizer is applied to increase the soil fertility. Mulching technology, which promotes fast growth of groundnut due to increase in the soil temperature at the germination stage, enables late sowing of groundnut after wheat (*Triticum aestivum*), barley (*Hordeum vulgare*), and vegetables. The major diseases are caused by *Diplodia natalensis*, *Corticium rolfsii*, *Sphaceloma arachidis*, *Mycosphaerella arachidis*, *Puccinia arachidis*, and *Ascochyta* sp. Major pests are *Anomala cuprea*, *Maladera castanea*, and *Meloidogyne hapla*.

Since the end of World War II, groundnut breeding in Japan has been promoted with two main objectives. The first was to breed early-maturing varieties for warm and cool areas. In these areas, spanish-type

1. Research Coordinator, Ecophysiology Research Division, Tropical Agricultural Research Center (TARC), Ministry of Agriculture, Forestry and Fisheries, 1-2, Ohwashi, Tsukuba, Ibaraki, 305, Japan.

Gocho, H. 1992. Breeding for eating quality of groundnut in Japan. Pages 367–372 *in* Groundnut – a global perspective: proceedings of an international workshop, 25–29 Nov 1991, ICRISAT Center, India (Nigam, S.N., ed.). Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

varieties grow well while other types grow poorly. Thus, breeding of a new spanish variety with seed the size of virginia types was undertaken, and two new cultivars, Wase-dairyu and Tachi-masari, were released. The second objective was to breed medium and/or late-maturing varieties. In Chiba Prefecture (one of the major groundnut-producing prefectures) in the beginning of the breeding program, new varieties were bred with basal node fruiting, early flowering, high yield (large number of pods), and early maturity associated with the decrease of flowers which did not produce fruits. The basal node fruiting character led to the improvement of the plant type as well as of the working efficiency and allowed close sowing in groundnut cultivation. The old cultivar, Chiba 43, was replaced by Chiba-handachi, and at present Chiba-handachi is being replaced by the new cultivar Nakate-yutaka, which was bred in 1979. Changes in the varieties and mulching technology increased groundnut yield considerably, allowed rotation of groundnut with other crops due to the shortening of the crop season of groundnut, and improved efficiency in mechanization. Through the development of the new cultivar Nakate-yutaka, the breeding objectives were achieved. However, at present, the most important objectives in groundnut breeding in Japan are high yield and quality.

In this paper the research achievements in quality breeding of groundnut in Japan are presented.

Quality Breeding of Groundnut in Japan

Much of the world's groundnut is utilized for oil extraction. In Japan, however, almost all the seeds are consumed after roasting of either whole pods or shelled nuts and as peanut butter. Therefore, eating quality and external quality of groundnuts are important.

Factors related to eating quality and testing methods

Eating quality by sensory test. Eating quality and related factors are tested using roasted seeds of cultivars Tachi-masari, Nakate-yutaka, Azuma-yutaka, and Chiba-handachi. Sensory testing was conducted by 15 experts, and sweetness, hardness, and eating quality (comprehensive judgement character) were scored into 5 grades from +2 to −2 with 0 for standard.

There is a high negative correlation between whole pod mass and eating quality. For the same level of yield varietal differences in eating quality exist, which enables the selection of a high-yielding variety with better eating quality.

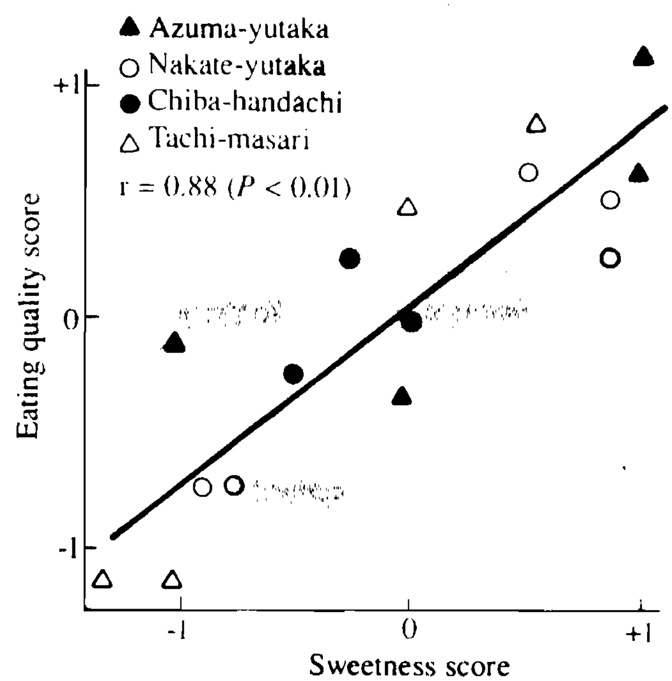


Figure 1. Relationship between sweetness and eating quality of groundnut. (Sensory testing was conducted by 15 experts: sweetness, hardness, and eating quality are scored in 5 grades from −2 to +2 with 0 for standard.) (Source: Yashiki and Takahashi 1983.)

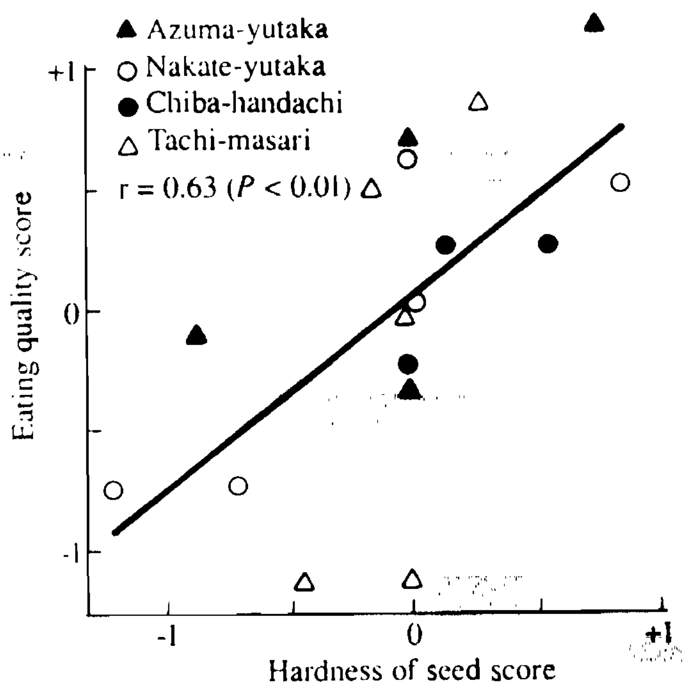


Figure 2. Relationship between seed hardness and eating quality of groundnut. (See Fig. 1.) (Source: Yashiki and Takahashi 1983.)

Relationships between sweetness and eating quality, and between hardness of seed and eating quality indicate that the eating quality increases with the increase of sweetness and hardness of seed (Figs. 1 and 2). However, the eating quality is more closely

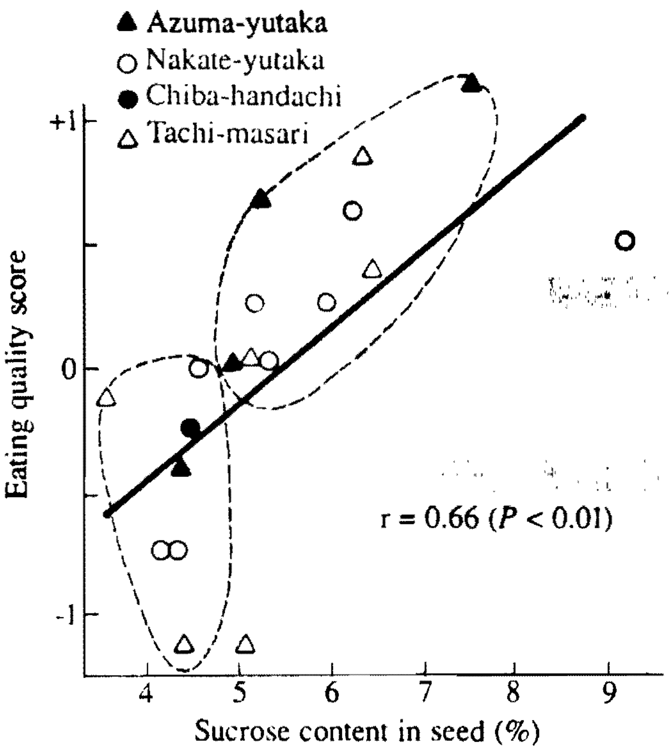


Figure 3. Relationship between sucrose content and eating quality of groundnut. (See Fig. 1.) (Source: Yashiki and Takahashi 1983.)

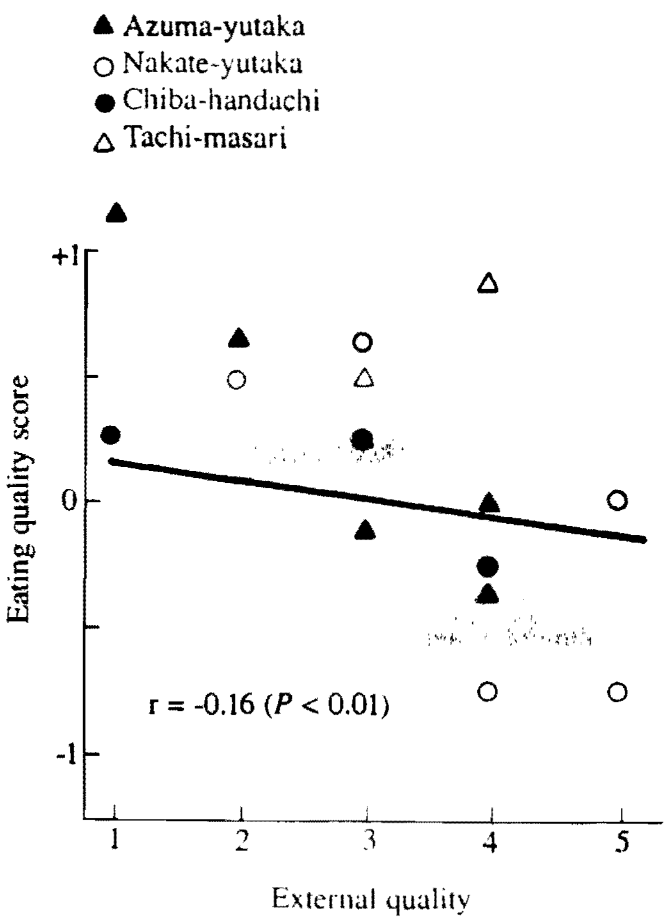


Figure 4. Relationship between external quality and eating quality of groundnut. (External quality was determined by appearance of seeds and pods, with 1 = good quality and 5 = poor quality.) (Source: Yashiki and Takahashi 1983.)

correlated with sweetness ($r = 0.88$) than hardness of seed ($r = 0.63$). This trend is particularly evident when the sucrose content in seed exceeds 5% (Fig. 3).

The correlation between external quality and eating quality ($r = 0.16$) is so low that good external quality as determined by appearance of pods and seeds is not necessarily associated with good eating quality (Fig. 4).

Based on these results, it is suggested that the sucrose content and hardness of the seed, which are most closely related to the eating quality, could be used as a indicators for the evaluation of the eating quality in tests.

Testing of seed hardness. Hardness of seed is measured by using the Kiya type of hardness meter. Testing involves the measurement of hardness [kg $(0.2\ cm^2)^{-1}$] when dry seed is crushed by downward pressure of the pillar of the hardness meter. Hardness value decreases when the water content of seed increases. Therefore, it is necessary to bring the moisture content of seed to a uniform level to obtain a reliable hardness value. As shown in Figure 5 all the varieties displayed stable hardness values when the water content ranged from 5 to 9%. In addition the relation between hardness determined by the hardness meter and the hardness determined by sensory tests showed about the same trend, namely stable values when the water content of seed ranged from 5 to 9%.

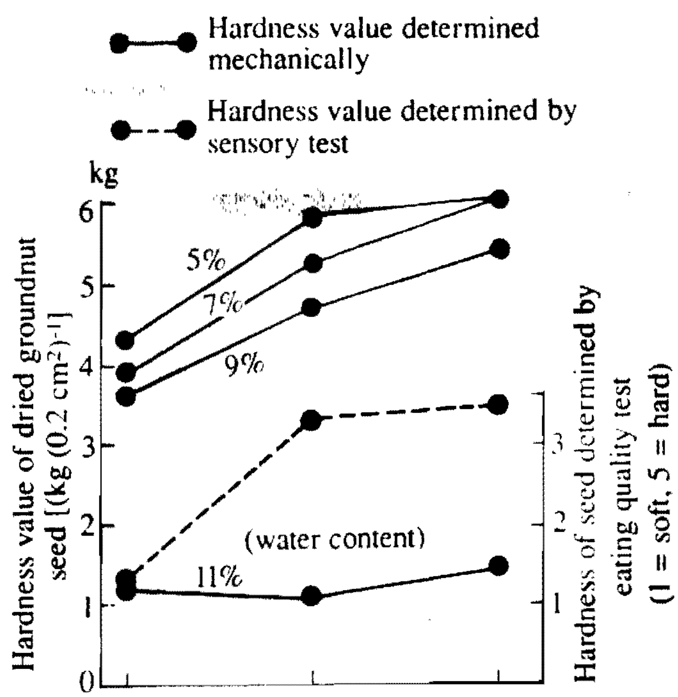


Figure 5. Relationship between hardness and water content of seed of three groundnut varieties. (Source: Yashiki and Takahashi 1983.)

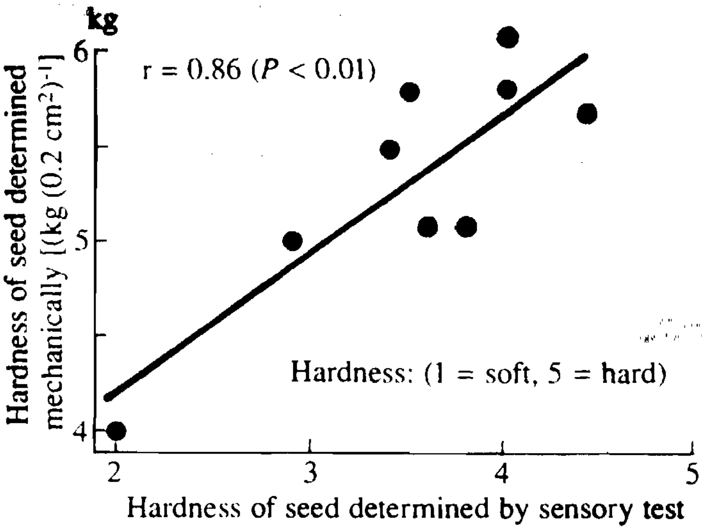


Figure 6. Relationship between seed hardnesses determined mechanically and by sensory test in nine groundnut varieties. (Source: Yashiki and Takahashi 1983.)

Therefore, the measurement of the hardness of seed should be made under a fixed seed water content in the range of 5 to 9%.

Application of this method to nine varieties revealed a high correlation coefficient (r = 0.86) between hardness determined mechanically and hardness determined by sensory testing as shown in Figure 6.

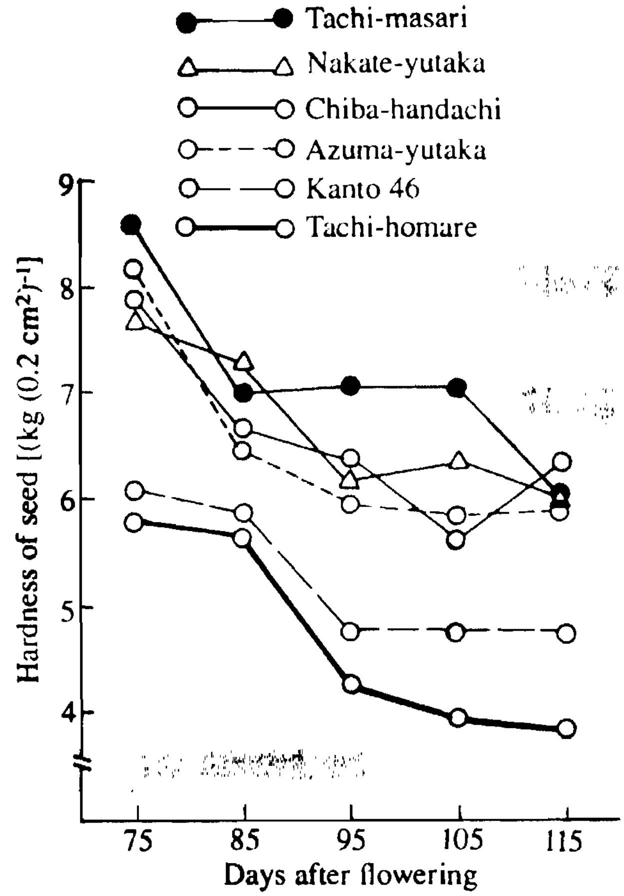


Figure 7. Relationship between harvesting time and seed hardness of groundnut. (Source: Yashiki and Takahashi 1984.)

Harvesting stage and change of seed quality

Seed hardness decreased with the delay in harvesting time as shown in Figure 7. As a rough estimate, although the hardness score expresses the characteristics of each variety, the scores at 85 days after flowering best express hardness of each variety. Therefore, for the selection of lines, hardness of seed should be determined 85 days after flowering.

Sucrose content of seeds decreased when the harvesting time was delayed (Fig. 8). The eating quality also showed a similar trend. Therefore, it appears that the sampling time for testing these characters is very important. The sucrose content should be analyzed at the optimum sampling time of the lines, based on the harvesting time, namely 75 days after flowering for early-maturing varieties, 80 to 85 days for medium-maturing varieties, and 95 days in late-maturing varieties.

For selection in groundnut breeding, seed hardness and sucrose content should be measured after the determination of other characters, because the inheritance of seed quality, especially eating quality, has not yet been demonstrated.

Present status of quality breeding and its constraints

Many studies on breeding in relation to the oil and protein content have been carried out in various countries. In Japan, however, only one study on the oil content and fatty acid composition of groundnut varieties was conducted by Taira et al. in the 1980s (personal communication) and no studies on protein breeding of groundnut are available in Japan.

As groundnut is a delicacy in Japan, external quality as well as eating quality is important. In the 1960s quality was added to the breeding objectives, and selection focused on the external appearance of seed and shell led to the release of the new cultivars Nakate-yutaka and Azuma-yutaka characterized by high yield and good quality. Both parental varieties showed a good external appearance.

For eating quality, it is evident that the sugar content is the most important factor. In the 1980s, breeding for eating quality was focused on crosses with varieties displaying a high sugar content.

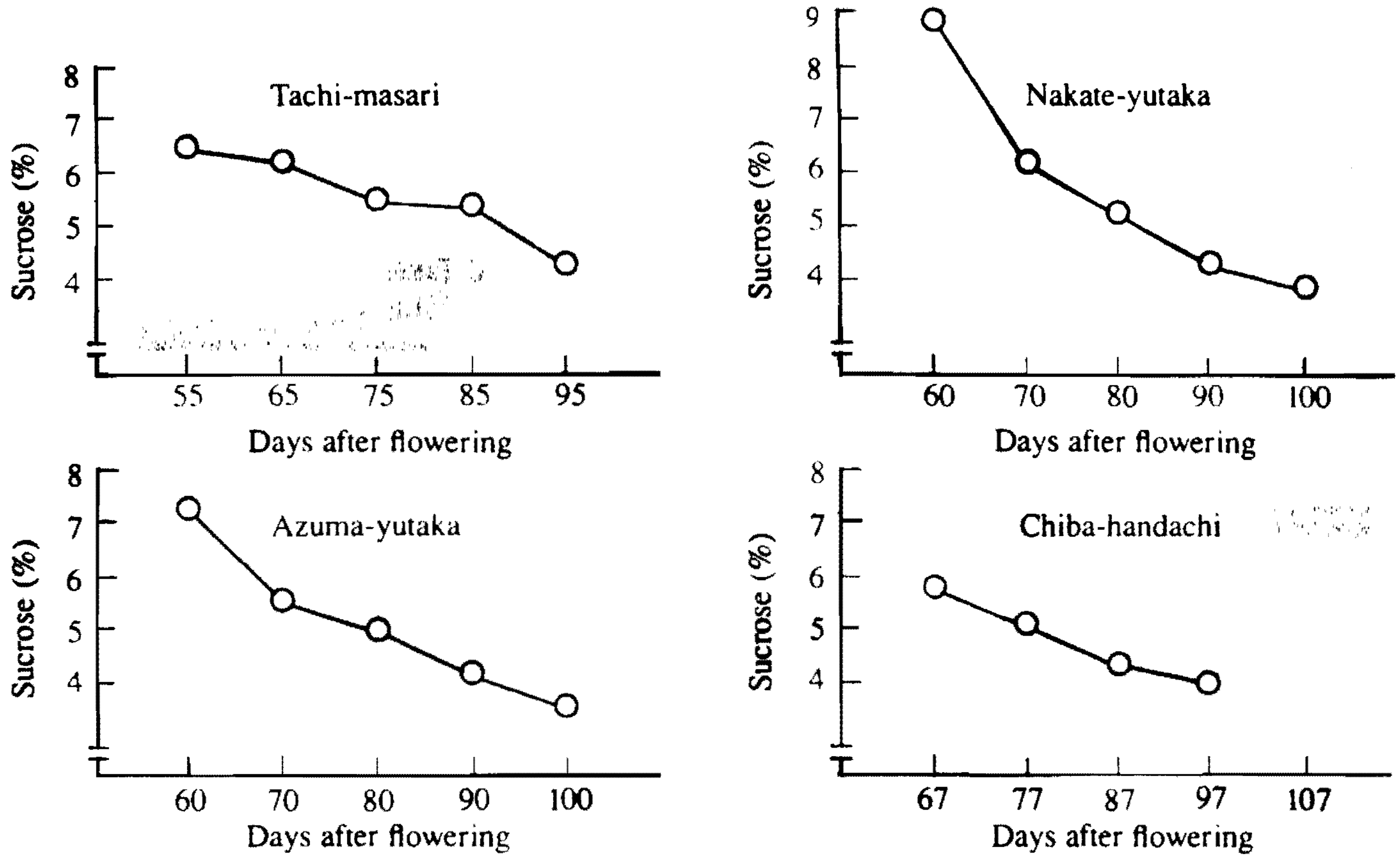


Figure 8. Change of sucrose content in groundnut seed of four cultivars with days after flowering. (Source: Yashiki and Takahashi 1984.)

In 1991, the Chiba Prefectural Agricultural Experiment Station, which has been designated as a center for groundnut breeding, released two new cultivars, Sayaka and Yude-rakka.

Sayaka was released as a recommended cultivar in Ibaraki Prefecture. The previously recommended cultivar Nakate-yutaka, which accounted for 60% of the area cultivated with groundnuts in Ibaraki, competed with rice (*Oryza sativa*) in harvesting. As a result, the quality deteriorated due to the delay in harvesting. In addition, Nakate-yutaka cracked easily due to its thin shell at the time of roasting for processing. The new cultivar Sayaka can be harvested at the optimum time after rice harvest and produces good quality groundnuts. This variety shows a higher yield, better quality, and is more suitable for roasting due to its thicker shell compared with Nakate-yutaka.

Yude-rakka was released as a recommended cultivar for boiled groundnut in the Kanagawa Prefecture. In this prefecture, unshelled whole pods and frozen boiled groundnuts are being marketed and promoted as a local specialty product. This variety shows early maturity, a taste as good as that of Nakate-yutaka, a white pod color with superior external appearance, and slightly constricted pods with only a small amount of soil sticking at harvest.

Both new varieties show an improved internal and external quality compared with the old varieties.

Literature Consulted

ARC (Agriculture Research Center). 1980. Breeding of legumes in Japan. (In Ja.) Research Series on Arable Farming no. 10. Kan-nondai, Ibaraki, Japan: ARC.

CAFRC (Chiba-ken Agriculture and Forestry Research Council). 1990. Systematized techniques of groundnut. Groundnut no. 1. (In Ja.) Chiba, Japan: CAFRC.

CAES (Chiba-ken Agricultural Experiment Station). 1991. Kanto 61, reference data for adopting a new groundnut variety. (In Ja.) Chiba, Japan: CAES.

CAES (Chiba-ken Agricultural Experiment Station). 1991. Kanto 68, reference data for adopting a new groundnut variety. (In Ja.) Chiba, Japan: CAES.

Maeda, K. 1974. Floral morphology and its application to the botanical classification of the peanut cultivars, *Arachis hypogaea* L. (In Ja. Summary in En.) Memoirs of the Faculty of Agriculture. Kochi, Japan: Kochi University.

TARC (Tropical Agriculture Research Centre). 1975. Useful crops in the tropics. (In Ja.) Tsukuba-gun, Ibaraki-ken, Japan: TARC.

Takahashi, Y., Takeuchi, S., Kamekura, H., Saito, S., Ishii, R., Ishida,Y., Nagasawa, J., and **Katura, H.** 1981. On the new variety "Nakateyutaka". (In Ja. Summary in En.) Bulletin of the Chiba-ken Agricultural Experiment Station 22:57-69.

Yashiki, T., and **Takahashi, Y.** 1983. Studies on the relation between cultivating methods and quality of peanuts. I. Eating quality factors and a simpler method to measure dry seed hardness. (In Ja. Summary in En.) Bulletin of the Chiba-ken Agricultural Experiment Station 24:43-49.

Yashiki, T., and **Takahashi, Y.** 1984. Studies on the relation between cultivating methods and quality of peanuts. II. The relation between time after flowering and quality of seeds. (In Ja. Summary in En.) Bulletin of the Chiba-ken Agricultural Experiment Station 25:55-60.

Discussion

Ousmane N'Doye: In one of your graphs you showed a harvesting date 50 days after flowering. Do groundnuts mature by that date, and how early do they flower?
H. Gocho: The sampling was done 50 days after flowering to measure the sugar content of the seed. It was done to observe the change in sugar content with harvesting time.

I.J. Godoy: What type of groundnut with good eating quality is cultivated in Japan – spanish, valencia or virginia types?
H. Gocho: In Japan the main groundnut type grown for eating is spanish with large seeds.

Workshop Recommendations

Time during the workshop did not permit a prioritization of constraints. We recognize that research programs must be based on resolving high priority constraints, in view of ever-diminishing financial resources. To do this, past recommendations and research accomplishments, presently perceived constraints, and future projections must be considered.

Socioeconomic Impact of Groundnut Research

It was stressed that despite the research on groundnut during the last decade (since the first International Groundnut Workshop), the general trend in productivity has been downwards. This point was considered to be worthy of investigation.

- A systematic constraint and systems analysis of groundnut production and utilization should take place in each country, by multidisciplinary teams using rapid rural assessment (RRA) and other techniques already available. This process should be on a continuing basis for 5 years, with training provided by ICRISAT and other organizations specializing in RRAs in the first year, so that NARS scientists can continue the process in succeeding years to provide a uniform regional analysis over an extended period.
- The results of these analyses should be used to prioritize the research and technology needs for each country and region. The analyses should also provide information on site-specific problems and farmers' needs.
- Technologies already available should be reviewed, and research planned only where new answers are required.
- Adequate on-farm research with farmer participation should take place to ensure that any technology developed is appropriate to small-holders, especially in rainfed areas. Impact measurement and mechanisms for feedback from farmers and extension workers must be included.
- Greater emphasis should be given to socioeconomic studies of the factors affecting adoption of groundnut technology and its impact. The socioeconomic implications of the technology to be implemented must be determined.
- Simulation studies could be used to investigate the potential impact of the changing economic and policy environments in the world.
- An integrated economic database on groundnut should be established by ICRISAT in conjunction with the Food and Agriculture Organization of the United Nations (FAO) and the Regional Coordination Centre for Research and Development of Coarse Grains, Pulses, Roots, and Tuber Crops in the Humid Tropics of Asia and Pacific (CGPRT). The University of Georgia, Agricultural Economics Department, maintains an extensive database on groundnut economics and can contribute to an integrated database in coordination with the Peanut Collaborative Research Support Program (CRSP).

Working Groups

- The value of working groups of persons conducting collaborative research to address particular constraints was endorsed, and it was suggested that the groups should visit relevant countries. The following topics were nominated as the subjects of International Working Groups, as part of the integrated pest management (IPM)/integrated resource management (IRM) subnetwork of ICRISAT:
  Aflatoxin management,
  Nematodes, and
  Soilborne diseases.
- The need for an international discussion group meeting on late leaf spot was mentioned.
- The workshop recommends that support be given to a meeting of groundnut genetic resources workers and appropriate groundnut researchers to discuss the need, form, and operation of a groundnut genetic resources network.

Training

- ICRISAT's human resources development efforts on groundnut should continue to be based on the needs to improve skills and knowledge as identified by NARS.
- Efforts to organize in-country specialized courses on groundnut technology by scientists from appropriate centers of excellence should continue.

Biotic Constraints

Biotic constraints to groundnut production (insects, diseases, and weeds) appear to command a large proportion of the resources available to groundnut research, undoubtedly as a result of the impact of such constraints on production and utilization of the crop. Their resolution was discussed during many sessions of the workshop. The following recommendations were made in order to improve the efficiency of the national and international programs aimed at their management. (In these recommendations, 'pest' includes weeds, diseases, insects, and other arthropods.)

- International programs of constraint identification are the highest priority prerequisite for the implementation of integrated pest management.
- Research on the components of IPM should be continued, but their interaction in farmers' fields should be evaluated as the first stage of IPM implementation. Farmers, NARSs, NGOs, and IAR Centers and organizations are natural partners in this process.
- Data on the factors that contribute to pest epidemics are needed to improve understanding of the pests' epidemiology. Appropriate technologies such as remote satellite imagery and GIS systems will assist in collection of such data, helping the development of management schemes and forecasting programs.
- The workshop strongly supported continued commitment to taxonomic, biological, and diagnostic studies of the biotic constraints and their biotypes, etc. This should include their natural enemies and pathogens. Specific mention was made of foliar diseases, millipedes, white grubs, viruses, nematodes, and thrips.
- Special attention was directed to the need to study pathogen variability on *Arachis* spp growing in their native habitats. It is not suggested that these studies were the role of ICRISAT.
- ICRISAT (and other groups) were asked to develop and provide short-duration material segregating for resistance to groundnut rosette virus to national programs in West Africa, and to strengthen epidemiological studies related to this disease.
- Weed problems and associated factors (labor availability, herbicide effectiveness, mechanization, etc.) require greater attention from national programs and international bodies.
- Models could be used to decide importance of genetic vs management solutions to biotic constraints. Developers of crop models should bear this requirement in mind.

Crop Agronomy

On numerous occasions during the workshop, reference was made to technologies capable of improving the efficiency of breeding programs that aim to minimize the effects of abiotic constraints. This led to the following recommendations.

- Both the national programs and ICRISAT should make more use of selection traits for water use efficiency (via carbon isotope discrimination and leaf thickness) in breeding programs to improve groundnut drought and aflatoxin resistance.
- ICRISAT should be requested to conduct research into selectable traits associated with root systems more efficient in water extraction.
- ICRISAT and national programs should collaborate in research into the application of and limits into exploiting the partitioning technology discussed at the workshop.
- Further research is justified to identify the sources of high and low temperature tolerance within *Arachis* germplasm. ICRISAT and national programs should collaborate in the quest for high temperature tolerance, while appropriate national programs should lead the search for low temperature tolerance.
- A working group of national program scientists should be formed to assist research into shade tolerance.
- Research into the nutritional and/or acid soil problems of specific regions should be conducted by national programs or other institutes with comparative advantage. It should be coordinated through working groups where appropriate. This should include research into identification of *Rhizobium* strains with tolerance to acid soil, and enhanced biological nitrogen fixation in acid soils.
- In order to reduce losses due to iron deficiency, national programs and ICRISAT should form collaborative links to assist selection for iron-efficient genotypes at early generations in breeding programs.
- Plastic mulch technology could be investigated by the national programs of relevant countries for adaptation and possible adoption, to bring new areas into groundnut production or improve the productivity of existing production areas.

- Crop management systems should be developed not only to improve agricultural production but also to ensure sustainability through maintenance of soil fertility, water-use efficiency, activity monitoring, disease and pest control, and protection of the environment.
- An advisory group should be formed to provide guidance as to the suitability of different types of models to the specific needs of the national programs. ICRISAT should be asked to initiate a network on modeling, and then work in collaboration with national programs to ensure that models are used to the best advantage of national programs.
- Training opportunities exist for better utilization of techniques of selection for water-use efficiency and partitioning, and the application of physiological models in data analysis. In collaboration with national programs and national scientists, ICRISAT could undertake this responsibility.

Genetic Resources and Germplasm Enhancement

Genetic resources are of immeasurable value to all interested in the resolution of the constraints to groundnut production. In view of the threat to groundnut germplasm resources worldwide, and the low level of interaction among groundnut genetic resources workers around the world, the lack of an overall priority for collection, evaluation, and conservation by the many centers around the world is viewed with concern. The continuing supply of newly collected germplasm, including hybrids and segregating material, was recognized as a prerequisite for sustaining genetically based research. The following recommendations emerged from the discussions:

- The ICRISAT international trials and nurseries should continue, and should be extended to newer areas. However, the results from these trials and nurseries should be more widely reported.
- National programs should be encouraged to assume regional responsibility of site-specific constraints.
- The importance of breeding for resistances to foliar diseases was reiterated. It was felt that the emphasis should be placed on the importance of agronomic suitability of resistant cultivars. In addition, forage value of these cultivars should also be evaluated. It seems desirable to strive for a moderate level of resistance. Collaboration among breeders, pathologists, and physiologists was stressed in disease resistance breeding. The group felt the need for breaking negative linkages between resistance and quality factors, more emphasis on moderate levels of multiple resistance, and integrated pest and disease management in tackling the biotic stresses.
- The transfer of genes conferring resistance to key pests from *Arachis* spp to *A. hypogaea* was considered to be of the highest priority.
- The need for greater emphasis on breeding early-maturing cultivars with limited seed dormancy was stressed. The increased efficiency of iron-absorption in short-duration lines was stressed. Intercropping, iron chlorosis, and wide diversity should be recognized as important traits in this material.
- As the future of groundnut is seen in the role of food rather than as an oil seed, the confectionery and quality questions were considered to be of importance. Requirements for confectionery and boiling types were discussed in detail. In view of conflicting requirements between countries, a suggestion was made to study these issues in depth to develop suitable guidelines for breeding.
- Poor availability of quality seed was identified as a major constraint to the adoption of improved cultivars. The need for subsidization of seed multiplication by government and/or donor agencies was recognized as an important factor in the sustainability of groundnut production.
- Simple but effective screening procedures, suitable for selecting within segregating material for aflatoxin, drought, cold, and acid-soil tolerance are needed.
- Biotechnology should be restricted only to those areas which cannot be resolved by conventional breeding. This includes the development of molecular markers.
- Delegates felt that ICRISAT should place more emphasis on hybridization, supply of germplasm and segregating material, and training for technical staff of the national breeding programs.

Groundnut Utilization

Many countries that earlier exported most of the groundnut produced, now consume most of the production domestically. The increased use of groundnut as a food rather than for oil, and the recognized value of the crop in sustainable cropping systems will likely result in greater production. Utilization technology is necessary to maintain the delivery of adequate quantities of quality products to both rural and urban consumers, which will profitably dispose of this produce and provide needed protein and energy in the food supply. Utilization research has not been a part of many national programs, so networking through groups such as this International Workshop is important to enhance the food use of groundnut. The following recommendations were made:

- Efforts should be made to breed groundnuts for more desirable processing, nutritional, and sensory qualities. Oil content and quality (oleic : linoleic ratio 1.6), protein content and quality (amino acid profiles), roasting quality, seed size and color, flavor, and texture improvement need to be addressed.
- Development of appropriate drying equipment for small farmers and for use on a village scale should be addressed. Economic rewards to farmers based on quality maintenance during drying and storage should be adopted on an international scale.
- Research to develop groundnut cultivars resistant to invasion by aflatoxigenic molds and subsequent aflatoxin production should continue. Growth and production of mycotoxins by other molds should be investigated. Research is needed on procedures for detoxification. Attention should also be given to anti-nutritional components, allergenic compounds, and flatulence-causing sugars in groundnut.
- The prospect for increased consumption of staple and snack foods containing groundnuts is good. Efforts should be expended to develop and/or improve these products. Promotion and marketing of these products becomes a marketing problem that will need increased research activity. Quality parameters that would lead to price discrimination at the buying point would be beneficial, and should be established.
- Research should be conducted to develop additional uses for groundnut shells and skins, thereby enhancing the economic return to the farmer, sheller, and processor.
- Attention should be given by groundnut production and utilization researchers to the role of women at the farm and market level. Drudgery associated with growing, harvesting, drying, processing, preparing, and marketing groundnuts should be addressed in terms of improving the quality of life.

The relative role of ICRISAT, donor agencies, and national programs in these areas of utilization development is unclear, and the issues remain for any group with the capability to address them.

Information Transfer

The need for transfer of information between farmers and scientists by the most appropriate technology was stressed. This workshop recommends support for:

- Continuation of SATCRIS;
- Centralized dissemination of groundnut information data bases through computer modems, and the training to support it;
- Publication of translations of existing literature identified by NARS as being important to their needs;
- Support for NARS scientists to publish in the international literature;
- A conference of information staff and information end-user scientists from NARS; and
- Publications and media aimed at solving farmers problems using information available.

Poster Abstracts

General

The Groundnut Crop

J. Smartt[1]

Groundnut is a crop of global economic significance not only for its widespread production but also for the even wider areas of processing and consumption. Major products and by-products are all sought-after material on world markets with a good history of relatively stable price levels and considerable potential for value-added processing.

It is opportune that its global significance be recognized in the production of a text which takes a global rather than a geographically narrow perspective. With this end in view, an attempt is being made to gather together, as far as is possible, the world experience of the crop through obtaining contributions from noted authorities in the field from all major producing areas. There is scope for further input, especially from those areas which are attempting to establish the crop or to increase their production to more significant levels. It is hoped that as a result of this Workshop held at ICRISAT, the overall input into this volume will be greatly enhanced. The objective is to make the text of value and interest to those involved in all aspects of production, marketing, processing, and manufacture. The pooling and sharing of experience should be a potent factor in the improvement of efficiency in research and development of the crop and its products and also bring considerable benefit to the producers, be they peasant farmers in the developing world or those engaged in high-tech production systems.

The contents aim to be as comprehensive as practicable and the present authorship represents a considerable geographic spread, which it is hoped can be extended further.

La culture de l'arachide

L'arachide est une culture d'importance économique mondiale, non seulement de par sa production, mais encore en raison de l'universalité de son traitement et de sa consommation. Les produits principaux et les sous-produits représentent un matériau très recherché sur les marchés du monde et l'histoire montre que les niveaux de prix ont été relativement stables et que son traitement offre un potentiel considérable de valeur ajoutée.

Il convient que son importance mondiale soit reconnue dans la production d'un texte qui adopte une perspective globale plutôt qu'étroitement géographique. Dans ce but, il s'agit de réunir, dans la mesure du possible, l'expérience mondiale de cette culture grâce à des apports d'autorités connues dans ce domaine, en provenance de toutes les principales zones productrices. D'autres intrants pourront s'y ajouter, particulièrement en provenance des zones qui s'efforcent d'établir cette culture ou d'en accroître la production pour parvenir à des niveaux significatifs. Il est à espérer qu'en conséquence de cet atelier qui s'est tenu à l'ICRISAT, l'intrant global dans ce volume sera encore largement renforcé . L'objectif consiste à faire en sorte que ce texte ait de la valeur et de l'intérêt pour ceux qui jouent un rôle dans tous les aspects de la production, de la commercialisation, du traitement et de la transformation. La mise en commun et le partage de l'expérience doit être un puissant facteur pour améliorer l'efficacité de la recherche et du développement de cette culture et de ses produits et aussi pour favoriser davantage les producteurs, qu'il s'agisse de petits paysans producteurs dans le monde en développement ou de ceux qui se livrent à des systèmes de production hautement technologiques.

La teneur de ce volume vise donc à être aussi générale que possible et ses auteurs actuels représentent un vaste éventail géographique qui, espérons-le, pourra être encore élargi.

---

1. Reader, Department of Biology, School of Biological Sciences, The University of Southampton, Bassett Crescent East, Southampton, Hants SO9 5NH, U.K.

Groundnut Production in Southwest Asia

Y.A. Ali[1] and A.L. Saeed[2]

There is no mention of groundnut area in the statistical books for Republic of Yemen, Saudi Arabia, and Oman as the crop is grown to a limited extent in the Southwest Asian region. Though it was felt a priority to improve groundnut area and production in the region, there are a number of environmental, technical, socio-economic, and organizational constraints to limit groundnut production. The major constraints that affect groundnut production include low yield potential of local varieties and nonavailability of latest technology, heavy infestations by termites (*Odontotermes* sp) and *Rhizoctonia* root rot, high cost of cultivation, and lack of marketing facilities and clear economic policy for oilseed crops. In addition, lack of farm equipment, a shortage of high-yielding resistant varieties to pests and diseases, and no progress in oilseed extraction are also responsible for low production of groundnut.

At present, groundnut produced in the region is used only for table purposes. It is a popular choice of farmers to use groundnut in intercropping with cotton (*Gossypium* spp) and cereal crops and to improve physical structure of the soil and soil management.

Various aspects of groundnut improvement have received attention in the research programs of Southwest Asian countries. They include climatic requirements, agronomic practices, and control of pests and diseases. Greater attention was also given to improve the economic condition of the farmers through an extension network and solving the problems of aflatoxins. The new production technology for increasing groundnut yield has been generated by El-Kod Agricultural Research Centre in Republic of Yemen and the recommendations include introduction of varieties such as NC 2 and Florunner, appropriate sowing dates, recommended spacing and fertilizers, investigations into response of *Rhizobial* culture, intercropping, and disease control.

The outline of future research programs on groundnut for the next decade include: a) correlations among yield components and their significance in breeding for resistance to environmental conditions and diseases, b) evaluating factors that affect evapotranspiration and yield response, c) carrying out research studies to bring improvement in the technology of groundnut cultivation and identify location-specific constraints, d) agronomic practices mainly relating to intercropping systems, and e) validation of fertilizer adjustment equation for different seasons and conditions.

The future outlook of the region's research program is aimed at improving groundnut production by acquiring sustainable varieties, improved technology to overcome the physical and biotic constraints, and provision of guidance and training facilities to the staff of the region. The cooperation and support of ICRISAT in fulfilling these objectives is greatly appreciated.

Production arachidière dans le sud de l'Asie

On ne trouve aucune mention de la superficie consacrée à l'arachide dans les manuels de statistiques pour la République du Yemen, l'Arabie Saoudite et l'Oman; la culture est pratiquée dans une mesure restreinte dans la région du sud-ouest de l'Asie. Bien que l'on reconnaisse l'importance d'améliorer la superficie plantée et la production dans cette région, bien des contraintes limitent la production arachidière, pour des raisons relatives à l'environnement, à la technique, à la socio-économie et à l'organisation. Les principales contraintes qui affectent la production arachidière comprennent le faible potentiel de rendement des variétés locales et l'absence d'une

1. Agronomist, Agronomy and Plant Breeding Section, El-Kod Agricultural Research Centre, Abyan, Aden, Republic of Yemen.
2. Head, Field Crops Research Section, Al-Boum Agricultural Research Station, Sana, Republic of Yemen.

technologie poussée, de violentes infestations de termites (*Odontotermes* sp) et la pourriture du pied (*Rhizoctonia)*, le coût élevé de la culture et l'absence de moyens d'action pour la commercialisation et d'une politique économique claire pour les cultures oléagineuses. En outre, le manque de matériel d'exploitation, la pénurie de variétés à haut rendement qui soient résistantes aux ennemis et maladies et l'absence de progrès pour l'extraction d'huile, ce sont là encore d'autres causes de la mauvaise production d'arachide.

A l'heure actuelle l'huile d'arachide produite dans la région sert uniquement à la consommation de bouche. Les cultivateurs préfèrent généralement cultiver l'arachide à titre intercalaire avec le cotonnier (*Gossypium* spp) et les céréales, servant ainsi à améliorer la structure physique du sol et sa gestion.

Divers aspects de l'amélioration de l'arachide ont préoccupé les programmes de recherches des pays du sud-ouest asiatique. Il s'agit notamment des exigences du climat, des pratiques agronomiques et de la lutte contre les ennemis et maladies. On se préoccupe davantage aussi d'améliorer les conditions économiques des cultivateurs, par l'application d'un réseau de vulgarisation et la solution du problème des aflatoxines. La nouvelle technologie de production destinée à accroître le rendement a été façonnée par le Centre de recherche agricole d'El Kod en République du Yemen et ses recommandations comprennent l'introduction de variétés comme NC 2 et Florunner, des dates de semis appropriées, des espacements et des engrais recommandés, des enquêtes sur la réponse de la culture au *Rhizobium*, les cultures associées et la lutte contre les maladies.

Les nouveaux programmes de recherche sur l'arachide pour la prochaine décennie comprennent: a) des corrélations entre les éléments du rendement et leur signification pour la sélection génétique en vue de la résistance aux conditions de l'environnement et aux maladies; b) l'évaluation des facteurs qui affectent l'évapotranspiration et la réponse du rendement ; c) des études de recherche pour améliorer la technologie de la culture et identifier des contraintes spécifiques aux emplacements; d) des façons agronomiques portant surtout sur des systèmes de cultures associées; et e) la vérification de l'équation d'ajustement d'engrais aux différentes saisons et conditions.

Le programme de recherche de la région visera à l'avenir à améliorer la production arachidière en faisant l'acquisition de variétés stables, l'amélioration de la technologie pour surmonter les contraints physiques et biotiques et la mise à disposition d'orientation et de formation pour le personnel de la région. La coopération et l'appui de l'ICRISAT pour parvenir à ces objectifs font l'objet d'une vive reconnaissance.

Groundnut Production and Research in Vietnam

Tran Van Lai[1], Nguyen Dang Khoa[2], Nguyen Huu Quang[3], and Nguyen Hai Nam[4]

Groundnut is an important food legume crop in Vietnam. Total annual area for groundnut is more than 200 000 ha, which indicates a significant increase since 1985. More than 90% of the groundnut is concentrated in three main producing regions of the country: the midland and plain areas of the North (71 000 ha), the northern part of the Central provinces (50 000 ha), and the Central Plateau and eastern part of South Vietnam (90 000 ha). Spring (February–June) is the main growing season in the North. Sowing occurs in the summer–autumn season (August–November) in nonirrigated upland. In the South, groundnut is grown in the rainy season (May–October) under rainfed conditions, and in the winter season (November–February) with supplemental irrigation.

Some good agronomic and crop management practices applied by the farmers are: raised bed sowing, hot water treatment of seed giving good germination after 8-9 months of storage in the North; and applying coconut ash, high population density, intensive pest protection, and supplemental irrigation in the South. However, lack of cash for input, low price at harvest time, lack of high-yielding varieties, pest and disease problems, water logging, and drought are still the main constraints to groundnut production in certain areas of Vietnam.

Research work is concentrated on testing and selecting high-yielding varieties for different areas. Some local varieties (Sen Lai, 79-85, Tran Xuyen, Bach Sa, and Ly Tuyen) and ICRISAT groundnut varieties (ICGVs 87132, 87130, 86005, and 86015) were found promising. The latter are being multiplied for further testing and release to the farmers. Moreover, other research on pest and disease control, applying phosphorus fertilizer and lime, and seed treatment with effective *Rhizobium* inoculant, are also in progress. A Groundnut On-farm Research program in collaboration with ICRISAT is operating in all main groundnut-growing regions of Vietnam.

Arachide: production et recherche au Vietnam

L'arachide est une importante légumineuse alimentaire au Vietnam. La superficie totale consacrée annuellement à l'arachide dépasse 200 000 hectares, ce qui représente un très nette augmentation depuis 1985. Plus de 90% de l'arachide est concentré dans trois principales régions de production du pays: les zones du milieu et des plaines du nord (71 000 hectares); la partie nord des provinces centrales (50 000 hectares) et le plateau central et la partie orientale du sud-Vietnam (90 000 hectares). Le printemps (février-juin) est la principale saison de culture dans le nord. Les semis se font pendant la saison été-automne (août-novembre) dans les terres non irriguées. Dans le sud, l'arachide est cultivée pendant la saison des pluies (mai-octobre) lorsqu'elle se fait dans des conditions pluviales et en hiver (novembre-février), avec complément d'irrigation.

Certaines pratiques satisfaisantes au point de vue agronomique et de la gestion des cultures sont appliquées par les cultivateurs: lit de semences surélevé, traitement à l'eau chaude des semences, assurant une bonne germination après huit à neuf mois de stockage dans le nord; application de cendres de noix de coco, forte densité du peuplement, protection intensive contre les ennemis et complément d'irrigation dans le sud. Toutefois, le manque d'argent pour les intrants, la faiblesse du prix de vente au moment de la récolte, l'absence de variétés à haut rendement, les problèmes des ennemis et des maladies, la saturation du sol par l'eau et la sécheresse représentent les principales contraintes de la production arachidière dans certaines région du Vietnam.

1. Director, Legumes Research and Development Center, National Institute of Agricultural Sciences, Hanoi, Vietnam.
2. Head, Legumes Division, Institute of Agricultural Science, Ho Chi Minh City, Vietnam.
3. Director, Department of Agriculture, Nghe Tinh Province, Vietnam.
4. Research Scholar (Crop Physiology), International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh 502 324, India.

Les travaux de recherches sont concentrés sur les tests et la sélection de variétés à haut rendement pour différentes régions. Certaines variétés locales (Sen Lai, 79-85, Tran Xuyen, Bach Sa, et Ly Tuyen) et des variétés d'arachide de l'ICRISAT (ICGV 87132, 87130, 86005 et 86015) semblent donner de bons résultats. Ces dernières sont en voie d'être multipliées pour de plus amples tests et distribution aux cultivateurs. En outre, d'autres recherches sont entreprises sur la lutte contre les ennemis et les maladies, l'épandage d'engrais phosphorés et chaulés, le traitement des semences au moyen d'un inoculant de *Rhizobium*. Un programme de recherche en milieu réel sur l'arachide en collaboration avec l'ICRISAT fonctionne dans la plupart des régions productrices d'arachide du Vietnam.

Groundnut Production and Research in China—Present and Future

Li Jianping[1]

Groundnut is one of the major oilseed crops in China. Generally, over 2.95 million ha is sown every year accounting for 2% of all crops and more than 25% of oilseed crops sown. The total output is nearly 5 million t a^{-1}, making up 40% of oilseed crop production. Its unit area yield is about 1.7 t ha^{-1} which ranks medium in the world. The export amounts 150 000 t a^{-1}. Groundnut production in China can be divided into seven regions. The main are provinces Shandong, Guangdong, Hebei, and Henan.

Favorable factors for promoting groundnut development are: reform in the rural economic system, widespread use of plastic mulch, extension of advanced varieties, increasing investment, and developing intensive field management. However, lack of cash for input, poor service after harvest, poor production condition, and disease and pest problems are still the main constraints to groundnut production in China.

China has paid attention to scientific research of groundnut. The aim of the breeding is to improve yield, disease resistance, and quality. Basic studies are also being carried out. In the coming years, yield levels will rise and production area also will increase. Field management and processing technique after harvest will be strengthened.

Arachide: production et recherche en Chine—aujourd'hui et demain

L'arachide est l'une des principales cultures oléagineuses de Chine. En général plus de 2,95 millions d'hectares sont semés chaque année, représentant 2% de toutes les cultures et plus de 25% des cultures oléagineuses. La production totale est de près de 5 millions de t a^{-1}, représentant 40% de la production de graines oléagineuses. Le rendement par unité de superficie est d'environ 1,7 t ha^{-1}. La production arachidière de la Chine est divisée en sept régions. Les principales sont les provinces de Shandong, Guangdong, Hebei et Henan.

Les facteurs qui favorisent le développement de la culture arachidière sont les suivants: réforme du système économique rural, usage élargi de paillis de plastique, l'extension de variétés avancées, l'augmentation des investissements et le développement de gestion intensive des terrains . Toutefois, le manque d'argent pour acheter des intrants, les mauvais services post-récolte, les mauvaises conditions de la production et les maladies et ennemis, tout cela continue a représenter des contraintes pour la production d'arachide en Chine.

La Chine s'est préoccupée des recherches scientifiques sur l'arachide. Le but de la sélection génétique est d'améliorer le rendement, la résistance aux maladies et la qualité. Des études de base sont également entreprises. Au cours des années à venir, les niveaux de rendement augmenteront et la zone de production aussi. La gestion du terrain et la technique du traitement post-récolte seront renforcées.

1. Project Manager, Scientific Management Department, Chinese Academy of Agricultural Sciences (CAAS), Beijing, People's Republic of China.

The Present Situation and Prospect of Groundnut Production and Scientific Research in China

Li Jianping[1]

Groundnut is one of the major oilseed crops in China and it ranks second both in the total acreage and production in the world after India. Chinese groundnut is a famous agricultural export product in the international market. The crop is cultivated throughout most of the country but the main production provinces are Shandong, Guangdong, Hebei, and Henan. During the last 10 years, China's groundnut production has been greatly increased because of regulation of agricultural production structure. Generally, each year its sowing area is about 3 million ha^{-1}, accounting for 2% of that of all crops and 25% of oilseed crops area. The total output is about 5 million t $year^{-1}$, making up 40% of oilseed crops production. Its unit area yield ranks medium in the world with about 1730 kg ha^{-1}. Annual exports amount to about 150 000 t.

China devotes much attention to its scientific research. It has been placed on key national programs involving multi researches on genetic improvement, breeding for high-yielding varieties, disease resistance, plant protection, new cultural methods, biological nitrogen fixation, quality traits, and postharvest technologies such as processing and storage. It has been accomplished with success in many areas. The yields of newly developed varieties are 5–10% more than the existing varieties besides their wide adaptation and resistance to various stress factors. With the strong extension network, 95% of total groundnut area is under the improved varieties.

Although some success has been achieved in scientific research, there are still some problems in further improving groundnut production in the country. At present, the research on aspects of seed quality and postharvest technologies is not adequate and we need to further improve on these. Efforts are also underway to increase total production in future by increasing unit area yield with the existing acreage by further strengthening its scientific research.

La situation actuelle et les possibilités de production d'arachide et de recherche scientifique en Chine

L'arachide est l'une des principales cultures oléagineuses de Chine et elle vient en deuxième après celle de l'Inde en ce qui concerne la superficie et la production. L'arachide chinoise est un produit agricole d'exportation célèbre sur le marché international. La culture se fait dans la majeure partie du pays mais les principales provinces productrices sont Shandong, Guangdong, Hebei et Henan. Au cours des dix dernières années, la production arachidière de la Chine a beaucoup augmenté, en raison de la régulation de la structure de production agricole. D'une façon générale, chaque année, la superficie plantée est d'environ 3 millions d'hectares, représentant 2% de celle de toutes les cultures et 25% de la superficie réservée aux cultures oléagineuses. La production totale est d'environ 5 millions de tonnes par an, représentant 40% de la production de graines oléagineuses de Chine. Le rendement par unité de surface est moyen dans le classement mondial, avec environ 1730 kg ha^{-1}. Les exportations annuelles s'élèvent à environ 150 000 tonnes.

La Chine consacre beaucoup d'attention à sa recherche scientifique. Elle figure parmi les principaux programmes nationaux comportant des recherches multiples sur l'amélioration génétique, la sélection pour obtenir des variétés à haut rendement, la résistance aux maladies, la protection des plantes, de nouvelles méthodes culturales, la fixation biologique de l'azote, des caractéristiques de qualités et les technologies post-récolte,

1. Project Manager, Scientific Management Department, Chinese Academy of Agricultural Sciences (CAAS), Beijing, People's Republic of China.

comme le traitement et le stockage. Le travail s'est fait avec succès dans bien des domaines. Les rendements de variétés développées récemment sont de 5-10% supérieurs à ceux des variétés existantes, outre leur meilleure qualité d'adaptation et de résistance à différents facteurs de stress. Grâce au réseau vigoureux de vulgarisation, 95% du total de la superficie consacrée à l'arachide est ensemencée avec des variétés améliorées.

Bien qu'un certain succès ait été obtenu par la recherche scientifique, il reste encore certains problèmes à résoudre pour améliorer la production arachidière nationale. A présent, la recherche sur les qualités de grains et les technologies post-récolte ne suffit pas et nous devons l'améliorer davantage. Des efforts sont également entrepris pour accroître à l'avenir le total de la production en élargissant le rendement par unité de surface et la superficie existante, en renforcant encore davantage la recherche scientifique.

Groundnut Production and the Crop Improvement in Shandong Province

Y. Shanlin[1]

The groundnut area in Shandong Province of China is about 740 000 ha with a total production of around 2 billion kg pods. This is the highest output of all provinces and accounts for 25% of the area and 30% of the production of the whole country.

The Shandong Peanut Research Institute (SPRI), founded in 1959, is the sole specialist groundnut research institute in China, and responsible for the Peanut Society affairs. Since 1985, 13 breeders among 150 employees at SPRI have developed 6 groundnut varieties which have been released by the Shandong Government. Varieties Luhua 6, 8, and 9, and 79266 and 8130 are of the virginia bunch type and 8122 belongs to spanish bunch type. All these varieties are sown in an area of 40 000 ha in more than 10 provinces of North China.

At present, lack of drought-tolerant and disease-resistant varieties are the main limiting factors to groundnut production in North China. Therefore, developing varieties tolerant to stresses [leaf spots, web blotch (*Phoma arachidicola*), nematodes, virus, and drought] is the key concern of groundnut breeders at SPRI over the next decade.

Production arachidière et amélioration des cultures dans la province de Shandong

La zone arachidière de la province de Shandong en Chine comprend environ 740 000 hectares et le total de la production est d'environ 2 tonnes de gousses. C'est la production la plus élevée de toutes les provinces et représente 25% de la superficie et 30% de la production du pays tout entier.

L'Institut de recherche arachidière de Shandong (SPRI), fondé en 1959 est le seul institut spécialisé dans la recherche arachidière en Chine et il est chargé des affaires de la Société arachide. Depuis 1985, treize sélectionneurs parmi les 150 employés par le SPRI ont développé 6 variétés d'arachide qui ont été vulgarisées par le gouvernement de Shandong. Les variétés Luhua 6, 8, et 9, et 79266 et 8130 sont du type buissonnant virginia et 8122 appartient au type buissonnant spanish. Toutes ces variétés sont semées dans une superficie de 40 000 hectares répartis entre plus de dix provinces du nord de la Chine.

A l'heure actuelle le manque de variétés résistant à la sécheresse et aux maladies représente le principal facteur limite de la production arachidière du nord de la Chine. C'est pourquoi le développement de variétés tolérantes au stress [taches foliaires, la marbrure (*Phoma arachidicola)*, les nématodes, les virus et la sécheresse], préoccupera les sélectionneurs du SPRI pendant la prochaine décennie.

1. Vice-Director, Shandong Peanut Research Institute, Laixi City, Shandong 266601, People's Republic of China.

Groundnut in Nepal

D.S. Pathic[1]

Groundnut is one of the most important oilseed crops of Nepal next to soybean (*Glycine max*), mustard (*Brassica campestris*), and linseed (*Linum usitatissimum*). Its area of concentration is in the ecological belts of Central and Eastern Terai with scattered distribution almost throughout the country. Because of the increasing importance of groundnut as an oilseed crop in Nepal, more oil extraction industries are being established.

There is a wide gap between the present level of yield and the production potential. There are a number of constraints that limit groundnut production in the country. They are grouped under environmental, technological, biological, socio-economic, topographical, institutional, infrastructural, and educational areas. Research work carried out in experimental stations to overcome some of these constraints has successfully led to some recommendations on the suitability of improved varieties, fertilizers application, doses and herbicides, plant protection measures, and mechanical operations. National Oilseeds Research Project (NORP) has so far identified two varieties, B 4 and Janak, which are widely grown in the country. Some of the recommendations under the network of NORP have made a substantial impact in the areas of adoption of improved varieties, agronomic practices, and plant protection.

Although groundnut is preferred by people for its wide range of food products, it does not get any encouragement in the marketing sector. There is no well organized marketing network and no clear-cut pricing policy for groundnut in the country. Nepal is a net importer of oilseeds including groundnut. Considering the demand and preference for the oil, there is an ample scope for increasing production of oilseed crops. The priorities have been chalked out in the areas of crop improvement and production technology for the next 10 years.

ICRISAT has been generous to NORP by supplying a large number of germplasm through the Asian Grain Legumes Network (AGLN) and some of the ICRISAT materials such as ICGS(E) 52, ICGS(E) 56, and ICGS 36 are in the pipeline. ICRISAT's contribution in the areas of providing training, information dissemination, organizing workshops, review meetings, and monitoring tours will greatly help in achieving the long-term goals of the national program.

L'arachide au Népal

L'arachide est l'une des plus importantes cultures oléagineuses du Népal, après le soja (*Glycine max*), la moutarde (*Brassica campestris*), et le lin (*Linum usitatissimum*). Sa zone de concentration se situe dans les ceintures écologiques du Terai central et oriental, avec une répartition éparpillée à travers le reste du pays. En raison de l'importance croissante de l'arachide comme culture oléagineuse, davantage d'industries d'extraction d'huile sont en voie d'établissement.

Il y a un grand écart entre le niveau actuel de rendement et le potentiel de production. Un certain nombre de contraintes limitent la production arachidière du pays. Elles ont trait à l'environnement, à la technologie, aux aspects biologiques, socio-économiques, topographiques, institutionnels, infra-structurels et éducatifs. Le travail de recherche effectué dans les stations expérimentales pour surmonter certaines de ces contraintes a mené avec succès à certaines recommandations sur l'utilisation de variétés améliorées, l'épandage d'engrais et les doses, ainsi que les insecticides, les mesures de protection des plantes, et des opérations mécanisées. Le projet national de recherche sur les graines oléagineuses (NORP) a déjà identifié deux variétés, B4 et Janak, qui sont largement cultivées dans le pays. Certaines des recommandations dans le cadre du NORP ont contribué utilement, sous forme de l'adoption de variétés améliorées, de façons agronomiques et de protection des plantes.

1. Coordinator, Agricultural Research Station, National Rice Research Program, Parwanipur, Nepal.

Bien que l'arachide soit préférée par la population pour sa vaste gamme de produits alimentaires, elle n'est pas favorisée dans le secteur de la commercialisation. Il n'y a aucun réseau de commercialisation bien organisé, ni aucune politique précise des prix de l'arachide. Le Népal est un importateur net de graines oléagineuses y compris l'arachide. Si l'on tient compte de la demande et de la préférence d'huile, une augmentation de la production de graines oléagineuses aurait une vaste portée. Des priorités ont été tracées quant à l'amélioration des cultures et à la technologie de la production pour les dix prochaines années.

L'ICRISAT a été très généreux au NORP en fournissant une grande quantité de ressources génétiques par le truchement du Réseau asiatique sur les légumineuses à grain (AGLN) et certains matériels de l'ICRISAT tels que l'ICGS (E) 52, l'ICGS (E) 56, et l'ICGS 36, qui sont en voie d'acheminement . L'apport de l'ICRISAT dans les domaines de la formation, de la diffusion d'information, de l'organisation d'ateliers, des revues de ré-examens de la situation et des visites de recyclage aidera largement à atteindre les objectifs à long terme du programme national.

Groundnut in Iran

H. Pourdavaie[1]

Groundnut is cultivated mostly in the northern part of Iran. In this area, 3000–6000 ha are sown each year under dry farming conditions. The average grain yield varies between 1800 and 2500 kg ha^{-1} according to the year and the rainfall.

Breeding activities are concentrated in new locations, especially in the southern part of Iran, for solving agrotechnical problems. Recently, the research program has been expanded to different parts of the country, mainly to find suitable new places for production and to increase groundnut cultivation under new program in the oilseeds research department.

We have two commercial varieties in the north named 'local' and 'NC 2'. We also have a small collection of other varieties. Breeding was our main project in the past and we have selected some new early-maturing lines from the variety 'Yugoslavia'. Besides that, we have determined agronomic practices for the area such as seed rate and sowing time.

Unfortunately there is no extraction of edible oil from groundnut in the country because all the production is taken up for nuts and confectionery. It is a profitable crop for farmers in view of its high price.

Under the aegis of our new program, we wish to expand our international cooperation with various research institutes in the world such as ICRISAT to acquire suitable new varieties, information, and technology to enable us to improve groundnut cultivation in our country. We were happy to receive 13 samples of different varieties of groundnut from ICRISAT in 1990.

The future of groundnut cultivation is very clear in Iran. Because of its high oil content, it has good potential to lead to self sufficiency in edible oil.

L'arachide en Iran

L'arachide est cultivée surtout dans le nord de l'Iran . Dans cette région, 3000–6000 hectares sont ensemencés chaque année dans des conditions d'aridoculture. Le rendement moyen en grain varie entre 1800 et 2500 kg par hectare selon l'année et la pluviosité.

Les activités de sélection sont concentrées dans des lieux nouveaux, surtout dans le sud de l'Iran, pour résoudre des problèmes d'agrotechnique. Récemment, le programme de recherche a été élargi pour couvrir différentes parties du pays, surtout afin de trouver de nouveaux endroits propices à la production et pour accroître la culture de l'arachide dans un nouveau programme relevant du département de la recherche sur les plantes oléagineuses.

Nous avons deux variétés commerciales dans le nord, appelées "locale" et "NC 2". Nous avons aussi une petite collection d'autres variétés. La sélection était précédemment notre projet principal et nous avons sélectionné certaines lignées à maturation précoce de la variété "Yugoslavia". En outre, nous avons déterminé les pratiques agronomiques qui conviennent à la région, telles que la quantité de semence et la date des semis.

Malheureusement, on ne fait aucune extraction d'huile comestible d'arachide dans le pays, parce que toute la production est absorbée comme arachide de bouche et de confiserie. C'est une récolte rentable pour les cultivateurs, car son prix est élevé.

Sous l'égide de notre nouveau programme, nous souhaitons élargir notre co-opération internationale avec divers instituts de recherche du monde entier, tels que l'ICRISAT, pour acquérir de nouvelles variétés qui

1. Head (Oilseeds Research Department), Seed and Plant Improvement Institute, Agricultural and Natural Resources Research Organization, Karadj, Iran.

conviennent, des informations et de la technologie pour nous permettre d'améliorer la culture arachidière de notre pays. Nous avons été heureux en 1990 de recevoir 13 échantillons de différentes variétés d'arachide de l'ICRISAT.

L'avenir de la culture de l'arachide est très clair en Iran. En raison de sa forte teneur en huile, cette culture a un excellent potentiel et pourra mener à l'auto-suffisance en huile comestible.

Groundnut Production: Perspectives

M.V. Nayudu[1]

India supports the world's largest groundnut area, however, only 50% of potential yield is realized. Constraints to groundnut productivity include the nonavailability of adequate quality seed of high-yielding cultivars, varieties lacking multiple disease resistance, sustainable cropping patterns, soil testing facilities for advising farmers on specific requirements, skilled use of farm equipment, crop growth monitoring in different regions, recommended quality pesticides and fertilizers, and drip irrigation facilities for effective utilization of water.

Remedial measures should aim to remove not only these constraints but also include integrated pest management, mechanization of harvesting, and development of storage facilities. On the marketing sector, it is essential to have suitable changes in the marketing policies to enhance production.

Production d'arachide: perspectives

L'Inde possède la zone arachidière la plus vaste du monde; toutefois, 50% seulement du rendement potentiel est obtenu. Les contraintes de la productivité comprennent l'absence de semences de bonne qualité pour obtenir des cultivars à haut rendement, des variétés disposant d'une résistance multiple contre les maladies, le type de culture durable, des moyens d'action pour tester les sols, et informer les cultivateurs des conditions spécifiques, un usage habile du matériel agricole, une surveillance de la croissance des cultures dans différentes régions, des pesticides et engrais de bonne qualité recommandée et des dispositifs d'irrigation au goutte à goutte pour utiliser efficacement l'eau.

Des mesures remédiables devraient viser non seulement à éliminer ces contraintes, mais encore à élaborer une maîtrise intégrée des ennemis, la mécanisation de la récolte et la construction d'entrepôts. Du point de vue de la commercialisation, il est essentiel de modifier suffisamment les politiques de commercialisation pour rehausser la production.

1. Professor of Virology, Sri Venkateswara University, Tirupati 517 502, Andhra Pradesh, India.

Present Position of Groundnut In Bangladesh

Mirza Md. Sirazul Hoque[1]

Groundnut ranks third in acreage, second in production, and first in yield among the oilseed crops in Bangladesh. Some 35 000 h of land are under groundnut cultivation. At present it contributes nearly 6% of the total area under oilcrops and 8% of the total oilseed production. About 83% of the crop is grown in 10 districts of Bangladesh, namely Noakhali, Kishoregonj, Barisal, Bhola, Dhaka, Faridpur, Sythet, Comilla, Patuakhali, and Mymensingh. There is scope for the expansion of groundnut area and increase of production in coastal areas and river banks.

There are four groundnut varieties recommended for cultivation. They are:

DA-1 (Maizchar badam). Spanish type; mostly 2-seeded pods, yield range 1600–2000 kg ha^{-1}, suitable for both rainy and postrainy seasons; there is no seed dormancy.

DG-2 (Basanti badam). High yielding virginia bunch type with 40–45 days dormancy in the seed. Bold seeded, yield range 2000–2200 kg ha^{-1}. Suitable for rainy season. Late in maturity (140–150 days) and tolerant to early leaf spot and rust.

DM-1 (Tridana badam). High yielding, dwarf valencia type, having no seed dormancy. About 55% 3-seeded pods, yield range 2200–2400 kg ha^{-1}. Suitable for intercropping; early in maturity (110–115 days); tolerant to early leaf spot and rust.

ACC-12 (Jhinga badam). Recently developed valencia type, no seed dormancy. Mostly 3-seeded pods; yield range 2100–2200 kg ha^{-1}. Suitable for intercropping in both seasons and good under stress conditions like saline and drought. Matures in 120–135 days; tolerant to early leaf spot and rust.

Many germplasm and breeding materials have been tested for resistance to diseases, early maturity, short dormancy in seeds, bolder seeds, higher yield, and a higher shelling percentage. In the spanish group ICG(E) 11 and ICG(E) 55 have been found promising compared to local spanish types. These two lines are now under advance tests. M 13 (virginia group) has also been found promising for higher yield and seed dormancy but requires longer time to mature (150–160 days) similar to DG 2.

At present most groundnut is consumed as roasted nuts and a little is used in confectionery for making biscuits and dry foods. Some sweets are also made of roasted nuts and molasses. Oil extraction is not possible unless production is adequately increased.

The main constraints are: 1) nonavailability of early (80–90 day) varieties with short seed dormancy (15–20 days), 2) lack of planters, diggers, and shellers, 3) shortage of good seed, and 4) lack of storage facilities. Storage techniques have been developed to improve viability. Seeds packed in polyethylene bags and stored in gunny sacks at about 9% moisture in the kernel retain adequate viability for more than 7 months.

Situation actuelle de l'arachide au Bangladesh

L'arachide est la troisième des cultures oléagineuses du Bangladesh quant à sa superficie, la deuxième quant à sa production, et la première quant à son rendement. Environ 35 000 hectares de terres sont réservés à l'arachide. A l'heure actuelle cela représente près de 6% de la superficie totale consacrée à des cultures oléagineuses et

1. Senior Scientific Officer, Oilseed Research Centre, Bangladesh Agricultural Research Institute, Joydebpur, Gazipur, Bangladesh.

environ 8% du total de cette production. Environ 83% de la culture se fait dans 10 districts du Bangladesh, à savoir: Noakhali, Kishoregonj, Barisal, Bhola, Dhaka, Faridpur, Sythet, Comilla, Patuakhali et Mymensingh. Il est possible d'élargir la superficie consacrée à l'arachide et d'accroître la production dans les zones cotières et sur les rives des rivières.

Quatre variétés d'arachide sont recommandées pour la culture. Ce sont:

DA-1 (Maizchar badam). Type spanish; surtout des gousses bigraines, avec des gammes de rendement de 1600–200 kg ha^{-1}, convenant à la saison des pluies et post-pluies; Il n'y a pas de dormance des semences.

DFG-2 (Basanti badam). Type virginia buissonnant à haut rendement à 40–45 jours de dormance de la semence. Gros grains, à gamme de rendement de 2000–2200 kg ha^{-1}, convenant à la saison des pluies. Maturité tardive (140–150 jours) et tolérant à la tache foliaire précoce et la rouille.

DM-1 (Tridam badam). Type valencia nain à haut rendement, sans dormance de semence. Environ 55% de gousses à trois grains; gamme de rendement 2200–2400 kg ha^{-1}. Convenant à la culture associée; maturité précoce (110–115 jours) tolérant la tache foliaire précoce et la rouille.

ACC-12 (Jingha badam). Type valencia récemment développé, sans dormance de semence. Surtout gousses à trois grains. Gamme de rendement 2100–2200 kg ha^{-1}. Convenant à la culture associée; dans les deux saisons et bonne dans les conditions de stress comme les terrains salins et la sécheresse. Maturité en 120–135 jours; tolérant la tache foliaire précoce et la rouille.

Bien des matériaux de ressources génétiques et de sélection ont été essayés pour la résistance aux maladies, la maturité précoce, une courte dormance des semences, des gros grains, un plus haut rendement et un pourcentage d'écossage plus fort. Dans le groupe spanish, ICG(E) 11 et ICG(E) 55 ont donné de bons résultats, en comparaison avec les types spanish locaux. Ces deux lignées suivent actuellement des tests poussés. M13 (groupe virginia) semble également promettre de bons résultats quant au rendement et à la dormance des semences, mais demande plus longtemps pour parvenir à maturité (150–160 jours), analogue à DG 2.

A présent, la majeure partie des arachides est consommée sous forme de grains torréfiés et très peu passe à l'usinage pour la biscuiterie et la fabrication d'aliments secs. Certaines confiseries sont également faites de grains d'arachide torréfiés et de mélasses. L'extraction d'huile n'est pas possible tant que la production ne sera pas suffisamment accrue.

Les principales contraintes sont: 1) absence de variétés précoces (80–90 jours) avec courte dormance des semences (15–20 jours), 2) manque de semoirs, planteurs et décortiqueuses, 3) manque de bonnes semences et 4) manque de bonnes installations de stockage. Des techniques de stockage on été mises au point pour améliorer la viabilité. Les semences enveloppées dans des sacs de polyéthylène et stockées dans des sacs de jute à environ 9% d'humidité dans le grain conservent une viabilité adéquate pendant plus de sept mois.

Groundnut Cultivation in Southwest Iran

A. Khodabandeh[1]

Research trials conducted at Saifabad Agricultural Research Center revealed that groundnut cultivation is possible in Koosestan. Some old varieties in these trials yielded up to 4·t ha^{-1}. New groundnut lines received from ICRISAT in 1989 were sown in preliminary trials in 1990. The yield of some of these lines is promising. In spite of the success of these trials, groundnut production on a large scale has not been possible owing to the lack of mechanical equipment for harvesting and enough extension services to help farmers with the crop.

Culture de l'arachide dans le sud-ouest de l'Iran

Des essais de recherche entreprises au centre de recherche agricole de Saifabad ont révélé que la culture de l'arachide est possible au Koosestan. Certaines vieilles variétés dans ces essais ont donné jusqu'à 4 tonnes par hectare. De nouvelles lignées d'arachide reçues de l'ICRISAT en 1989 on été semées dans des essais préliminaires en 1990. Le rendement de certaines de ces lignées semble promettre. En dépit du succès de ces essais, la production arachidière sur grande échelle n'a pas été possible en raison de l'absence de matériels mécaniques pour la récolte et de services de vulgarisation suffisants pour aider les cultivateurs dans leurs efforts.

1. Saifabad Agricultural Research Center, Dezful, Iran.

Production Techniques and Research of Groundnut in Indonesia

A. Kasno and N. Saleh[1]

Groundnut is grown both as wetland (*sawah*) and rainfed or dryland (*tegal*) crop in different agroecological zones of Indonesia, but the main concentration is in Java and South Sulawesi. Groundnut usually yields best on sandy loam soils with 150–200 mm rainfall per month if nutrients are sufficient. It is grown either as a sole crop or intercropped with maize (*Zea mays*), cassava (*Manihot esculenta*), and other legume crops. The importance of this crop is indicated by its increasing demand over the last decade for use in a variety of food preparations as well as livestock feed.

Almost 50% of the farmers grow spanish type local varieties that mature in 85–90 days, and the rest are recommended cultivars such as Gajah, Macan, Banteng, Pelanduk, Tapir, Kelinei, and Anoa. The latter two varieties are tolerant to early leaf spot (*Cercospora arachidicola*), late leaf spot (*Phaeoisariopsis personata*), and rust (*Puccinia arachidis*). So far, 16 improved varieties of groundnut have been released in the country, and most of them mature in 95–110 days. All the released varieties are resistant to bacterial wilt (*Pseudomonas solanacearum*). Farmers prefer varieties with pink medium-sized seed with two seeds per pod, and early maturing and erect types.

The agroclimatic environment of Indonesia is very diverse and the constraints that limit production are also enormous. Low production of groundnut is often caused by water stress and disease infestation, mainly leaf spots, rust, and peanut stump virus. Some of the other constraints encountered by farmers under various growing conditions include poor drainage and soil compaction, nutrient deficiency, poor cultural practices, nonavailability of seed for improved varieties, lack of fertilizer application and crop protection, and problems in postharvest technology and storage. In addition, an unfavorable marketing system and nonavailability of recommended package of practices for groundnut also result in low productivity.

Research strategy making effective use of available manpower, budget, research direction, and facilities to overcome the major constraints is implemented by the National Coordinated Research Program (NCRP). The Central Research Institute of Food Crops (CRIFC) has the responsibility to coordinate and carry out the tasks of the Agency for Agricultural Research and Development (AARD) in the food crops subsector. They have formulated some major issues relating to future research direction to improve the crop yields. They include: 1) improvement of crop establishment, 2) breeding new varieties, 3) improvement of crop management, 4) knowledge on occurrence and control of diseases and pests, 5) improvement of grain quality and reduction of postharvest losses, and production economics, and 6) utilization.

Agricultural production in Indonesia has to be viewed under multidisciplinary and multiagency efforts. Collaborative research on groundnut between CRIFC, the Australian Centre for International Agricultural Research (ACIAR), ICRISAT, and the Netherlands' Royal Tropical Institute in many areas of interest such as crop improvement, information transfer, and training is very effective.

Techniques de production et recherche sur l'arachide en Indonésie

L'arachide est cultivée tant dans les terres humides (*sawah*) que dans les terres pluviales ou en aridoculture (*tegal*) dans différentes zones agro-écologiques de l'Indonésie, mais la principale concentration est à Java et dans

1. Groundnut Breeder and Virologist, Malang Research Institute for Food Crops (MARIF), Malang, East Java, Indonesia.

le sud des Célèbes. L'arachide vient généralement bien dans les sols de limon sablonneux avec 150–200 mm de pluie par mois, si la teneur nutritive du sol est suffisante. On la cultive soit en culture pure, soit en culture associée avec du maïs (*Zea mays)*, du manioc (*Manihot esculenta)* et d'autres légumineuses. L'importance de cette culture est indiquée par la demande croissante formulée depuis une décennie d'usage dans bien des préparations alimentaires aussi bien que pour l'affouragement du bétail.

Près de 50% des cultivateurs cultivent des variétés locales du type spanish qui parviennent à maturité en 85–90 jours, et le reste sont des cultivars recommandés tels que Gajah, Macan, Banteng, Pelanduk, Tapir, Kelinei et Anoa. Ces deux dernières variétés sont tolérantes à la tache foliaire précoce (*Cercospora arachidicola*), à la tache foliaire tardive (*Phaeoisariopsis personata*) et à la rouille (*Puccinia arachidis*). Jusqu'à présent 16 variétés d'arachide ont été vulgarisées dans le pays et la plupart d'entre elles parviennent à maturité entre 95–110 jours. Toutes les variétés vulgarisées résistent au flétrissement bactérien (*Pseudomonas solanacearum*). Les cultivateurs préfèrent des variétés à semences roses de dimension moyenne avec deux grains par gousse, et les types à maturation précoce et érigés.

L'environnement agro-climatique de l'Indonésie varie beaucoup et les contraintes qui limitent la production sont énormes. La faible production de l'arachide est souvent causée par le stress hydrique et l'infestation pathologique, surtout les taches foliaires, la rouille et le virus du rabougrissement de l'arachide. Certaines des autres contraintes subies par les cultivateurs dans différentes conditions de culture comportent un mauvais drainage et la compaction du sol, une déficience des éléments nutritifs, de mauvaises façons culturales, la non disponibilité de semences de variétés améliorées, le manque d'épandage d'engrais et de protection des cultures et des problèmes de technologie post-récolte et de stockage. En outre, un système de commercialisation défavorable et la non disponibilité d'ensembles recommandés de pratiques pour l'arachide réduisent également la productivité.

La stratégie de recherches qui tire bien parti de la main d'oeuvre disponible, du budget, de la direction des recherches, et des moyens d'action pour surmonter les principales contraintes est appliqué par le Programme national de recherches coordonnées (NCRP). L'institut central de recherche sur des cultures alimentaires (CRIFC) a la responsabilité de coordonner et d'appliquer les tâches de l'Agence pour la recherche agricole et le développement. (AARD) dans le sous-secteur des cultures alimentaires. Cette agence a formulé différentes idées majeures relatives à la direction ultérieure des recherches pour améliorer le rendement. Il s'agit notamment de: 1) amélioration de l'établissement de la culture; 2) sélection de nouvelle variétés; 3) amélioration de la gestion des cultures; 4) connaissances sur l'apparition des maladies et des ennemis et la lutte contre eux; 5) amélioration de la qualité du grain et réduction des pertes post-récolte, économie de la production; et 6) utilisation.

La production agricole en Indonésie doit être envisagée dans le cadre des efforts pluridisciplinaires et multi-agences. La recherche en collaboration sur l'arachide entre le CRIFC, le Centre australien de recherche agricole internationale (ACIAR), l'ICRISAT, et l'Institut tropical royal des Pays-Bas dans bien des domaines d'intérêt comme l'amélioration de la culture, le transfert d'information et la formation, est très efficace.

The SADCC/ICRISAT Groundnut Project

G. Schmidt, G.L. Hildebrand, and P. Subrahmanyam[1]

The Southern African Development Coordination Conference (SADCC)/ICRISAT Groundnut Project was established at Chitedze Agricultural Research Station near Lilongwe, Malawi in 1982 It serves the ten SADCC Member States covering a large area of diverse agroclimatic conditions. Groundnut is an important food and cash crop to small-holder farmers but yields are very low, varying between 400 and 700 kg ha^{-1}. Constraints are many and varied. The two factors that affect production in all the countries of the region are diseases [early leaf spot (*Cercospora arachidicola*) and rosette] and lack of suitable varieties. The major objective of the project is to develop high-yielding breeding lines with resistance to factors limiting production in the region. We have developed a technique for rosette resistance screening and annually several hundreds of germplasm and breeding lines are screened. Recently, a new source of resistance to rosette has been identified for the first time in non-West African germplasm lines. Progress has been made in incorporating rosette resistance into high-yielding virginia genotypes. Strategies for effective management of early leaf spot are being investigated. We have supplied superior breeding lines to national programs for evaluation and one of our lines, ICGMS 42, has shown outstanding performance. It has been released for cultivation in Malawi and Zambia. We organize regional workshops, specialist group tours, and steering committee meetings, and provide training in breeding and pathology at the technician level.

Le projet arachidier SADCC/ICRISAT

Le projet arachidier de la Conférence de coordination du développement en Afrique australe (SADCC/ICRISAT) a été établi à la station de recherche agricole de Chitedze, près de Lilongwe, Malawi en 1982. Il dessert les dix états membres de la SADCC, couvrant une vaste zone de conditions agro-climatiques diverses. L'arachide est un aliment important et une culture de rente pour les petits cultivateurs, mais les rendements sont très faibles, variant entre 400 et 700 kg ha^{-1}. Les contraintes sont nombreuses et variées. Les deux facteurs qui affectent la production dans tous les pays de la région sont les maladies [tache foliaire précoce (*Cercospora arachidicola)* et rosette] et le manque de variétés qui conviennent. Le principal objectif du projet est de développer des lignées de sélection à haut rendement qui résistent aux facteurs limites de la production de cette région. Nous avons mis au point une technique pour le criblage de la résistance à la rosette et annuellement une centaine de ressources génétiques et de lignées de sélection sont criblés. Récemment une nouvelle source de résistance à la rosette a été identifiée pour la première fois dans des lignées de ressources génétiques qui ne venaient pas d'Afrique occidentale. Des progrès ont été effectués en incorporant la résistance à la rosette dans des génoptypes de virginia à haut rendement. On recherche des stratégies pour la gestion efficace de la cercosporose ou tache foliaire précoce. Nous avons également fourni des lignées de sélection supérieures aux programmes nationaux aux fins d'évaluation et l'une de nos lignées, l'ICGMS 42, a manifesté une performance remarquable. Elle a été vulgarisée pour la culture au Malawi et en Zambie. Nous organisons des ateliers régionaux, des tournées spécialisées pour groupes, et des réunions de comité, et nous fournissons de la formation à la sélection et à la pathologie au niveau technicien.

1. Principal Groundnut Agronomist, Principal Groundnut Breeder, and Principal Groundnut Pathologist, SADCC/ICRISAT Groundnut Project, P.O. Box 1096, Lilongwe, Malawi.

Area, Production, and Yield in the Gambia

Sait Drammeh[1]

The Gambia is one of the smallest countries in West Africa. Between 80 and 90% of the country's population lives in rural areas where local crop production is the major source of income and food. Groundnut production accounts for 87% of the Gambia's export earnings and occupies about 59% of the total cultivated land. During the period 1980 to 1990, total annual groundnut cultivation varied between 65 900 ha and 110 000 ha with an average over the period of 91 500 ha. The corresponding average annual yield was 1222 kg ha^{-1} and average production was 104 264 t.

Owing to the erratic nature of the rainfall pattern in the last decade, three groundnut varieties of different maturity duration have been recommended for cultivation in the Gambia. Yields over the period 1987-1990 were: 2113 kg ha^{-1} (55/437); 2176 kg ha^{-1} (73/33); and 2187 kg ha^{-1} (28/206).

Promising varieties received from ICRISAT include ICGS(E) 52, Robut 33-1 (Kadri 3), JL 24, and J 11.

Superficie, production et rendement en Gambie

La Gambie est l'un des plus petits pays d'Afrique occidentale. Entre 80 et 90% de la population du pays vit dans des parages ruraux, où la production locale de culture est la principale source de revenus et d'alimentation. La production arachidière compte pour 87% des revenus d'exportation de la Gambie et environ 59% du total de la superficie cultivée. Pendant la période de 1980–1990, la culture arachidière annuelle totale a varié entre 65 900 et 110 000 hectares, avec une moyenne pendant la période de 91 500 hectares. Le rendement annuel moyen correspondant était de 1222 kg ha^{-1} et la production moyenne de 104 264 tonnes.

En raison des caprices de la pluviosité durant la dernière décennie, trois variétés d'arachide de photopériodes différentes ont été recommandées pour la culture en Gambie. Les rendement pendant la période 1987–1990 étaient de 2113 kg ha^{-1} (55/437); 2176 kg ha^{-1} (73/33); et 2187 kg ha^{-1} (28/206).

Des variétés qui promettent ont été reçues de l'ICRISAT, y compris ICGS(E) 52, Robut 33-1 (kadri 3), JL 24, et J11.

1. Senior Research Officer, Department of Agricultural Research, Yundum Research Station, The Gambia.

Evolution of Groundnut Yields in Argentina

G.H. Giandana[1]

Groundnut yields have been almost steady for the last 50 years (1932–1982) in Argentina with an annual mean of 736 kg of kernels ha^{-1} and an increment of 1.8 kg of kernels ha^{-1} $year^{-1}$. Valencia type cultivars were mostly sown during that period. The kernels were mainly used for oil production. Confectionery groundnut exportation began in 1975 and it was necessary to adopt a better crop technology in order to obtain a higher quality product.

Adoption of new technology and better cultivars has increased the groundnut yields since 1982. The mean yield for 1991 was 1358 kg of kernels ha^{-1} with an annual yield increment of 28.38 kg. The main advances in crop technology can be summarized as:

- Crop rotation including sorghum (*Sorghum bicolor*) and corn (*Zea mays*);
- Sowing of new virginia runner-type cultivars (Florunner and Florman INTA) in 70% of the groundnut-growing areas;
- Efficient control of weeds and diseases like *Cercospora* spp;
- Higher performance in harvesting due to the use of a digger-shaker-inverter; and
- Changes in local trade (farmers now sell the product in-shell).

Once the use of the digger-shaker-inverter and better combines increases, a significant increment in groundnut yield is expected. At present, around 20–25% of potential yield is lost at harvesting. The release of better cultivars and crop management technologies will also help in increasing the groundnut yield.

Evolution des rendements d'arachide en Argentine

Les rendements d'arachide sont demeurés pratiquement stables depuis 50 ans (1932–1982) en Argentine avec une moyenne annuelle de 736 kg de grains ha^{-1} et une augmentation de 1,8 kg de grain ha^{-1} par an. Les cultivars du type valencia étaient généralement semés pendant cette période. Les grains servaient surtout à la production d'huile. L'exportation d'arachide de confiserie a commencé en 1975 et il a été nécessaire d'adopter une meilleure technologie des cultures pour obtenir un produit de qualité supérieure.

L'adoption d'une nouvelle technologie et de meilleurs cultivars a augmenté les rendements de l'arachide depuis 1982. Le rendement moyen pour la période 1991 était de 1358 kg de grains ha^{-1} avec une augmentation annuelle de rendement de 28,38 kg. Les principaux progrès de la technologie de culture peuvent être résumés comme suit:

- Rotation de cultures y compris le sorgho (*Sorghum bicolor)* et le maïs (*Zea mays*);
- Semis de nouveaux cultivars virginia du type rampant (Florunner et Florman INTA) dans 70% des zones où l'on cultive l'arachide;
- Lutte efficace contre des adventices et les maladies comme *Cercospora* spp;
- Meilleure performance de la récolte, grâce à l'usage d'un dispositif d'arrachoir-secoueur-inverseur; et
- Changements du commerce local (les cultivateurs vendent maintenant leurs produits en coque).

Lorsque l'usage des arrachoirs-secoueurs-inverseurs et de meilleures combines augmentera, on prévoit une hausse significative du rendement de l'arachide. A l'heure actuelle environ 20–25% du rendement potentiel est perdu à la récolte. La vulgarisation de cultivars meilleurs et de technologie de gestion des cultures aidera aussi à accroître le rendement de l'arachide.

1. Groundnut Breeder, Estacion Experimental Agropecuaria del INTA, 5988–Manfredi, Cordoba, Argentina.

Groundnut Development Action Project in the Philippines

C.R. Escaño, and L.V. Buendia[1]

The national average yield of groundnut in the Philippines remains low (0.75 t ha^{-1}) despite the government thrust for countrywide development. Low productivity has been attributed to low technological input from farmers and the use of groundnut as an intercrop with other upland crops rather than as the primary crop.

Technology piloting on groundnut production was launched in 1987 by the Philippine Council for Agriculture, Forestry and Natural Resources Research and Development (PCARRD), and other concerned government and private agencies in three major groundnut-growing regions of the country. It demonstrates to groundnut farmers the merit of using the recommended component technology (RCT), which consists primarily of using newly developed high-yielding and pest-resistant varieties.

Yield from pilot production trials using RCT consistently exceeded that from traditional farmers practice (TFP) across all sites. An average yield of 1032 kg ha^{-1} was obtained by farmers who used RCT against the average yield of 611.50 kg ha^{-1} obtained from TFP. Comparative analysis of the economic benefits gave an average Return on Investment (ROI) of 90% in using RCT as compared to TFP's average ROI of 22%.

The enormous potential of using the RCT prompted PCARRD to launch the peanut technology commercialization program that will cover about 15 500 hectares in Cagayan Valley and Ilocos Region within a period of 3 years to be participated in by a total of 62 500 farmers.

Projet d'action pour le développement arachidier aux Philippines

Le rendement national moyen d'arachide aux Philippines demeure faible, (0,75 t ha^{-1}) en dépit des efforts du gouvernement pour développer les régions rurales. La faible productivité a été attribuée à un mauvais intrant technologique des cultivateurs et à l'usage d'arachide comme culture associée avec d'autres cultures pluviales plutôt que comme culture primaire.

La technologie pilote de la production arachidière a été lancée en 1987 par le conseil des Philippines pour la recherche et le développement de l'agriculture de la foresterie et des ressources naturelles (PCARRD) et d'autres organisations du gouvernement et du secteur privé dans trois régions principales de culture de l'arachide. Le conseil démontre aux cultivateurs qui cultivent de l'arachide les avantages de se servir de technologie d'éléments recommandés (TER) qui comportent surtout l'usage de variétés résistant aux ennemis et à haut rendement qui ont été développées récemment.

Le rendement d'essai de production pilote au moyen de TER dépassent constamment celui des cultivateurs traditionnels (PCT) dans tous les emplacements. Un rendement moyen de 1032 kg ha^{-1} a été obtenu par des cultivateurs au moyen du TER contre le rendement moyen de 611,50 kg ha^{-1} au PCT. L'analyse comparative des avantages économiques montre un rapport moyen sur l'investissement de 90% au moyen du TER en comparaison avec la moyenne de 22% pour le PCT.

L'énorme potentiel du TER a incité PCARRD à lancer le programme de commercialisation de technologie arachidière qui couvrira environ 15 500 hectares dans la vallée de Cagayan et la région d'Ilocos pendant une période de trois ans, avec la participation de 62 500 cultivateurs au total.

1. Director and Head of Database Management, Crops Research Division, the Philippine Council for Agriculture, Forestry and Natural Resources Research and Development, Los Baños, Laguna, Philippines.

Transferring Improved Groundnut Production Technology in India

C.S. Pawar, K.C. Jain, J.V.D.K. Kumar Rao, P.W. Amin, and D.G. Faris[1]

ICRISAT, in collaboration with the National Agricultural Research System (NARS), conducted several on-farm trials and demonstrations on improved groundnut production technology in India during 1987–1990. The trials contained four treatments – improved package with improved variety, improved package with local variety, local package with improved variety, and local package with local variety. Each treatment was grown on an area of 0.2 ha. An average yield benefit of 20% was recorded with the adoption of the improved package alone and 26% with the adoption of improved varieties alone. With the adoption of both the improved package and varieties, the average yield benefit was 61% with the net economic benefit almost double that of the local package and varieties. The raised-bed system of land preparation was found to be an important component of the improved package. The improved technology, recommended by the All India Coordinated Research Project on Oilseeds (AICORPO), and strongly supported by agencies such as the National Dairy Development Board (NDDB), Anand, Gujarat, has now been accepted by groundnut farmers.

Transfert de la technologie améliorée de la production arachidière en Inde

L'ICRISAT, en collaboration avec le système national de recherche agricole (NARS) a entrepris plusieurs essais en milieu réel et démontré une technologie améliorée de production arachidière en Inde pendant les années 1987-90. Les essais ont comporté quatre traitements: amélioration de l'ensemble avec variété améliorée, amélioration de l'ensemble avec variété locale, ensemble local avec variété améliorée, et ensemble local avec variété locale. Chaque traitement était cultivé sur une superficie de 0,2 hectare. Un avantage moyen de rendement de 20% à été noté avec l'adoption de l'ensemble amélioré seul et 26% avec l'adoption de variété améliorée seule. Lors de l'adoption à la fois de l'ensemble amélioré et des variétés améliorées, l'avantage moyen de rendement était de 61% avec l'avantage économique net presque du double de l'ensemble et variété locaux.. Le système des planches sur-élevées pour la préparation du lit de semences a joué un rôle important dans l'ensemble amélioré. La technologie améliorée, recommandée par le projet coordonné de recherche de toute l'Inde sur les graines oléagineuses (AICORPO) et fortement appuyée par des institutions comme l'Office national de développement de la laiterie (NDDB), Anand, Gujarat, a maintenant été adoptée par les producteurs d'arachide.

1. Entomologist, Plant Breeder, Crop Physiologist, Senior Entomologist, and Principal Coordinator (AGLN), International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh 502 324, India.

Groundnut: Improved Production Technology for Uttar Pradesh

A.B. Singh and O.B. Singh[1]

Groundnut is one of the premier oilseed crops of India. It has a special significance for Uttar Pradesh, where it contributes about 25% of India's total edible oil production. There are several factors responsible for low yield of groundnut in Uttar Pradesh. A constraint analysis suggests ten important reasons for decline in area, production, and yield levels of groundnut in the state, namely: 1) cultivation of groundnut on poor and marginal soils, 2) vagaries of monsoon, 3) biotic stresses (white grub and bud necrosis disease), 4) abiotic stresses (moisture stress at pegging and podding stage), 5) farmer's ignorance to adopt improved technology, 6) use of very low seed rate (50% of recommendation), 7) use of traditional varieties, 8) application of high dose of nitrogen (60–120 kg ha^{-1}), 9) high seed cost, and 10) farmers do not adopt any plant protection measures.

The improved production technology developed for increasing groundnut yields includes: 1) field preparation: two to three plowings, 2) varieties: Chitra, Kaushal, and Chandra, 3) sowing time: 20 June to 7 July, 4) seed rate: Chitra - 60 kg, Kaushal - 65 kg, Chandra - 75 kg ha^{-1}, 5) spacing: 30 × 10 cm (Kaushal), 45 × 15 cm (Chitra and Chandra), 6) fertilizers: 15 N: 30P: 45K (kg ha^{-1}), 7) gypsum: 300 kg ha^{-1}, 8) plant protection: seed treatment with thiram at 3 g kg $seed^{-1}$, soil treatment with thimat at 20 kg ha^{-1}, 9) irrigations: one or two protective irrigations at flowering and fruiting, and 10) weedings: two, one at 15–20 days after sowing, and the other at 20-35 days after sowing.

Arachide: technologie améliorée pour la production en Uttar Pradesh

L'arachide est l'une des premières cultures oléagineuses de l'Inde. Elle a une signification spéciale pour l'Uttar Pradesh, où elle représente environ 25% du total de la production d'huile comestible de l'Inde. Il y plusieurs facteurs qui sont la cause de la faiblesse de rendement de l'arachide en Uttar Pradesh. Une analyse de contraintes semble montrer deux raisons importantes de la baisse de superficie, de production et de rendement d'arachide dans cet état, à savoir: 1) culture de l'arachide dans des sols pauvres et marginaux; 2) caprices de la mousson; 3) stress biotique (scarabéidés blancs et maladies de la nécrose des pousses); 4) stress abiotique/stress hydrique à l'étape et de la formation de gousses; 5) ignorance du cultivateur quand il s'agit d'adopter une technologie améliorée; 6) usage d'un très faible taux de semence (50% de la recommandation); 7) usage de variétés traditionnelles; 8) épandage d'une dose élevée d'azote (60–120 kg ha^{-1}); 9) coût élevé de la semence; 10) les cultivateurs n'adoptent pas de mesure de protection de la culture.

La technologie de production améliorée mise au point pour obtenir des rendements croissants d'arachide comprend: 1) préparation du terrain: 2 à 3 labours; 2) variétés: Chitra, Kaushal, et Chandra; 3) date des semis: 20 juin au 7 juillet; 4) taux de semis: Chitra - 60 kg, Kaushal - 65 kg, Chandra - 75 kg par hectare; 5) espacement: 30 × 10 cm (Kaushal), 45 × 15 cm (Chitra et Chandra); 6) engrais: 15 N: 30P: 45K kg ha^{-1}; 7) gypse: 300 kg ha^{-1}: 8) protection des plants: traitement des semences au Thyram à 3g kg de semence, traitement du sol au Thimat à 20 kg ha^{-1}: 9) irrigation: 1 ou 2 irrigations de protection à la floraison et à la nouaison 10) sarclages: 2, 1 à 15–20 jours après le semis et l'autre à 20–35 jours après le semis.

1. Groundnut Breeder and Senior Technical Assistant, Groundnut Research Station, Mainpuri 205 001, Uttar Pradesh, India.

Genetic Resources

Distribution and Resource Potential of Groundnut Landraces

A.K. Sadasivan, A.K. Singh, and M.H. Mengesha[1]

Landraces of crop plants are considered as one of the primary resources of genetic diversity. They have received a high priority for collection and genetic conservation. Of the 12 841 accessions of groundnut germplasm assembled at the Genetic Resources Unit, ICRISAT Center, 5 500 are landraces. An attempt has been made to classify the landraces for important agronomic traits, and for resistance to various diseases and pests, and to identify their main centers of origin. The results of the analysis indicate that there is a wide range of variability among the available germplasm. Further, it shows that much variability for resistance to both diseases and pests, and also for agronomically important traits, has originated mainly from primary and secondary centers of diversity in South America. However, the degree of variability for agronomic characteristics is similar in centers of diversity and in countries of extensive cultivation (India, China, USA, etc.), where human pressure for economic criteria has prevailed.

Distribution et potentiel de ressources des races locales d'arachide

Les races locales sont considérées comme l'une des ressources essentielles de la diversité génétique. Elles ont reçu une priorité élevée pour la collecte et la conservation génétiques. Sur les 12 841 obtentions de ressources génétiques d'arachide assemblés à l'unité de ressources génétiques au centre de l'ICRISAT, 550 sont des races locales. On a essayé de classer les races locales d'après des aspects agronomiques importantes et d'après leur résistance à diverses maladies et divers ennemis et pour identifier leurs centres principaux d'origine. Les résultats de l'analyse indiquent qu'il y une vaste gamme de variabilités entre les ressources génétiques disponibles. En outre on peut voir qu'une grande partie de la variabilité pour la résistance aux maladies et aux ennemis et pour les aspects importants du point de vue agronomique dérive surtout de centres primaires et secondaires de diversité d'Amérique du Sud. Toutefois, le degré de variabilité pour les caractéristiques agronomiques est analogue dans les centres de diversité et dans les pays de culture extensive (Inde, Chine, Etats-Unis, etc.) où la pression humaine quant aux critères économiques a dominé.

1. Research Associate, Germplasm Botanist, and Principal Germplasm Botanist, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh 502 324, India.

Assessment of Seed Quality Traits in Wild *Arachis* Species

R. Jambunathan, A.K. Singh, Santosh Gurtu, and K. Raghunath[1]

Several wild *Arachis* species have resistance to pests and diseases. Some of them have been used successfully in resistance breeding programs. We analyzed the *Arachis* wild species, to assess the variability in components of nutritional quality. Seventeen germplasm accessions of wild species representing six sections of the genus *Arachis* were grown in uniform-size pots under controlled greenhouse conditions. Seeds were analyzed for protein, oil, amino acid composition, fatty acid composition, trypsin, and chymotrypsin inhibitors. Seed proteins were extracted and separated using polyacrylamide gel electrophoresis. Data obtained on cultivated groundnut — ICGSs 1, 5, 11, 21, and 44 — were used for comparison. Results suggest that several wild *Arachis* species can be potential resources for certain quality attributes and be safely used in a breeding program.

Evaluation d'aspects de la qualité des semences dans les espèces d'arachide sauvage

Plusieurs espèces sauvages d'*Arachis* ont de la résistance aux ennemis et aux maladies. Quelques uns d'entre eux ont servi aux programmes de sélection pour la résistance. Nous avons analysé les espèces spontanées d'*Arachis* pour évaluer cette variabilité des éléments de qualité nutritive. Dix-sept obtentions de ressources génétiques d'espèce sauvage représentant six sections du genre *Arachis* ont été cultivées dans des pots de dimension uniforme dans des conditions de serre contrôlées. Les semences étaient analysées quand à leur teneur en protéines, en huile, leur composition en acides aminés, leur composition en acides gras, en trypsine et les inhibiteurs de chimotrypsine. Les protéines et semences ont été séparées au moyen de l'électrophorèse en gélose de polyacrylamide. Les données obtenues sur les arachides cultivés — ICGS 1, 5, 11, 21 et 44 — ont servi à la comparaison. Les résultats semblent montrer que plusieurs espèces sauvages d'*Arachis* peuvent être des ressources potentielles de certains attributs qualitatifs et peuvent être utilisées sans danger dans un programme de sélection.

1. Principal Biochemist, Germplasm Botanist, Senior Research Associate, and Research Associate, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh 502 324, India.

Biotechnology

Use of Wild Species in Groundnut Improvement

J.P. Moss, Nalini Mallikarjuna, and A.K. Singh[1]

Wild species contain a wealth of resistances, many of which are in species that can be crossed with groundnut. Wild species have been screened by ICRISAT scientists and collaborators, and immune and/or resistant sources for important pests and diseases have been identified. These include rust (*Puccinia arachidis*), early leaf spot (*Cercospora arachidicola*), and late leaf spot (*Phaeoisariopsis personata*), peanut stripe virus, peanut mottle virus, aphids (*Aphis craccivora*), leaf miner (*Aproaerema modicella*), *Spodoptera*, and root borer (*Sphenoptera indica*).

Derivatives containing genes from wild species have been produced. Several thousands of lines with desired characters have been selected by ICRISAT breeders for use in crossing programs, and by cell biologists for use elsewhere. They have been donated to the ICRISAT gene bank, and made available to various national agricultural research systems on request. So far, 67 consignments have been sent to 26 countries. Derivative ICGS 50, with multiple resistance for pests and diseases, is in regional trials in Tamil Nadu and several others have entered the All India Coordinated Trials. Derivatives of wild species showed resistance to PStV in Indonesia, and to groundnut rosette virus in Malawi. They have been used as parents in a crossing program in China, and the selections are in multilocational trials.

Usage d'espèces sauvages pour l'amélioration de l'arachide

Des espèces sauvages contiennent une vaste gamme de résistance, dont un grand nombre dans des espèces qui peuvent former des hybrides avec l'arachide. Des espèces sauvages ont été criblées par les scientifiques de l'ICRISAT et leurs collaborateurs et on a identifié des sources d'immunité et de résistance à d'importants ennemis et maladies. Il s'agit notamment de la rouille (*Puccinia arachidis*), de la cercoscopore précoce des feuilles (*Cercospora arachidicola*), et de la tache tardive des feuilles (*Phaeoisariopsis personata*), du virus strié de l'arachide, du virus de la marbrure de l'arachide, des aphidés (*Aphis craccivora*), de la mineuse des feuilles (*Aproaerema modicella*), du spodoptéra et du boreur des racines (*Sphenoptera indica*).

Des dérivés contenant des gènes d'espèces spontanées ont été produits. Plusieurs milliers de lignées présentant des caractéristiques désirables ont été sélectionnées par les sélectionneurs de l'ICRISAT pour l'usage dans des programmes de croisement et par les biologistes des cellules pour l'usage ailleurs. Ils ont été donnés à la banque de gènes de l'ICRISAT et mis à la disposition de divers systèmes nationaux de recherche agricole sur demande. Jusqu'à présent, 67 obtentions ont été envoyées à 26 pays. Le dérivé ICGS 50, à résistance multiple contre les ennemis et les maladies, figure dans des essais régionaux au Tamil Nadu et plusieurs autres ont figuré dans les essais pan-indiens coordonnés. Les dérivés d'espèces sauvages ont montré de la résistance aux PSTV en Indonésie et au virus de la rosette de l'arachide au Malawi. On s'en est servi comme géniteur dans un programme d'hybridation en Chine et des sélections figurent dans des essais multilocaux.

1. Principal Cell Biologist, Cell Biologist, and Germplasm Botanist, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh 502 324, India.

Transformation of Groundnut

Nalini Mallikarjuna[1], J.P. Moss[1], W. Powell[2], and A. Kumar[2]

Research on transformation is being done in collaboration with the Scottish Crop Research Institute (SCRI), Dundee, U.K., funded by the Overseas Development Administration (ODA). ICRISAT scientists have been closely involved with the research and one scientist worked for 3 months at SCRI. Initial experiments showed that wild strains of *Agrobacterium tumefaciens* could induce crown galls on groundnut, and also established the sensitivity of groundnut to kanamycin and hygromycin. Cotyledons were treated with Construct PKU 2 and shoots produced. On the selection medium, these were green, chimeric, or white. Green shoots were subcultured onto fresh selection medium, and surviving shoots were positive for ß-glucuronidase (GUS) assay.

Transformation de l'arachide

La recherche sur la transformation est entreprise en collaboration avec l'Institut de recherche sur les cultures d'Ecosse (SCRI), à Dundee, R.U., financée par le ministère du développement outre-mer (ODA). Les scientifiques de l'ICRISAT ont collaboré étroitement avec cette recherche et un scientifique a travaillé pendant trois mois au SCRI. Les expériences initiales montrent que les souches sauvages d'*Agrobacterium tumefaciens* pourraient induire des galles du collet sur l'arachide et ont également montré la sensibilité de l'arachide à la kanamycine et à l'hygromycine. Les cotylédons étaient traités au moyen du Construct PKU 2 et produisaient des pousses. Sur le support de sélection, les pousses étaient vertes, chimériques ou blanches. Les pousses vertes étaient subculturées dans un support de sélection frais, et les pousses qui survivaient étaient positives pour le titrage de Beta-glucuronidase (GUS) R.U.

1. Cell Biologist and Principal Cell Biologist, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh 502 324, India.

2. Head and Senior Scientist, Cellular and Molecular Genetics Group, Scottish Crop Research Institute (SCRI), Invergowrie, Dundee DD2 5DA, U.K.

Tissue Culture of Groundnut

Nalini Mallikarjuna[1], J.P. Moss[1], and D.C. Sastri[2]

Extensive experiments have established protocols for regeneration from a number of explants. Plants have been established from cultivated genotypes and wild species. Cotyledons are the best material, although root and shoot formation has been induced on leaflet segments and on hypocotyl. Although response is excellent with wild species, a number of genotypes of groundnut have been successfully cultured. The level of regeneration of shoots and/or embryoids has been satisfactory for initial experiments on transformation.

Culture de tissus de l'arachide

D'importantes expériences ont établi des protocoles pour la régénération d'un certain nombre d'explants. Des plants ont été établis à partir de génotypes cultivés et d'espèces sauvages. Les cotylédons sont les meilleurs matériaux, bien que la formation de racines et de pousses ait été induite sur des segments de petites feuilles et sur l'hypocotyle. Bien que la réponse soit excellente avec les espèces sauvages, un certain nombre de génotypes d'arachide ont été cultivés avec succès. Le niveau de régénération des pousses et/ou des embryoides a été satisfaisant pour des expériences initiales sur la transformation.

1. Cell Biologist and Principal Cell Biologist, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh 502 324, India.
2. Cell Biologist, formerly ICRISAT. Now at: A.V. Thomas and Company Ltd., Cochin 682 015, Kerala, India.

Wide Crosses in Groundnut

Nalini Mallikarjuna[1], J.P. Moss[1], A. Venkateshwar[1], D.C. Sastri[2], and Zhang Xinyou[3]

Introgression from Section *Rhizomatosae*. Hybrids with species in section *Rhizomatosae* have been produced using hormone-aided pollinations and embryo rescue, through ovule or embryo culture. Hybrid plants were difficult to establish in pots, and showed morphological variations, especially in flower structure. Hybridity was confined by morphology, isozyme patterns, and cytology. Meiosis was irregular.

Introgression from Section *Erectoides*. *Erectoides* species are diploids, therefore a number of *Erectoides* × *Erectoides* diploid hybrids have been produced, and treated with colchicine to produce 40 chromosome amphiploids, which have been crossed with *A. hypogaea*. Although introgression from *Erectoides* should be possible through the above procedure, we continue to attempt the cross *A. hypogaea* with *Erectoides* diploids.

Hybrides élargis de l'arachide

Introgression de la Section *Rhizomatosae*. Des hybrides avec des espèces de la section *Rhizomatosae* ont été produits en se servant de pollination aidée par hormones et de récupération d'embryon par culture d'ovule ou d'embryons. Des plants hybrides étaient difficiles à établir dans des pots, et manifestaient des variations morphologiques, spécialement quant à la structure des fleurs. L'hybridité était limitée par la morphologie, les structures des isozymes et la cytologie. La méiose était irrégulière.

Introgression de la section *Erectoides*. Les espèces d'*Erectoides* sont diploïdes et donc un certain nombre d'hybrides *Erectoides* × *Erectoides* ont été produits et traités à la colchicine pour produire 40 amphiploïdes de chromosomes, qui ont été croisés avec *A. hypogaea*. Bien que l'introgression d'*Erectoides* soit possible par la méthode ci-dessus, nous continuons à essayer de faire des hybrides d'*A. hypogaea* avec des diploïdes d'*Erectoides*.

1. Cell Biologist, Principal Cell Biologist, and Research Associate, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh 502 324, India.
2. Cell Biologist, formerly ICRISAT. Now at: A.V. Thomas and Company Ltd., Cochin 682 015, Kerala, India.
3. Research Scholar, formerly ICRISAT. Now at: Henan Academy of Agricultural Sciences, Henan, The People's Republic of China.

In Vitro Germination of Excised Embryos of Groundnut

Adib Sultana[1], M.K. Jana[2], A.K. Singh[1], S. Chandrapal[1], and M.H. Mengesha[1]

Germplasm conservation in groundnut is limited by rapid loss of seed viability and seed size. To investigate the possibility of conservation of excised embryos, we attempted in vitro differentiation of excised embryos and seedling establishment. Embryos were excised from mature seeds of ICG 221. They were cultured on Murashige and Skoog (MS) medium with and without hormones (kinetin 1 and 3 mg L^{-1}, indole-butyric acid 1 and 3 mg L^{-1}), under 16 h daylength. Of the different combinations of nutritional and hormonal media, half MS with 10 g L^{-1} sucrose and 0.2% activated charcoal gave the maximum germination, differentiation, and establishment of in vitro derived plants (60%). Efforts are in progress to conserve excised embryos.

Germination in-vitro d'embryons excisés d'arachide

La conservation des ressources génétiques chez l'arachide est limitée par une perte rapide de viabilité des semences et par la dimension des semences. Pour étudier la possibilité de conservation d'embryons excisés, nous avons essayé une différenciation in-vitro d'embryons excisés et d'établissement de plantules. Les embryons étaient excisés de semences matures d'ICG 221. Ils étaient cultivés sur un support Murashige et Skoog (MS), avec ou sans hormones (kinétine 1 et 3 mg L^{-1}, acide indole-butyrique 1 et 3 mg L^{-1}), sous 16 heures de lumière du jour. D'après les combinaisons différentes de supports nutritifs et hormonaux, la moitié des supports MS avec 10 g L^{-1} de saccharose et 0,2% de charbon de bois activé donnait le maximum de germination, de différenciation, et d'établissement de plants dérivés in-vitro (60%). Des efforts sont entrepris pour conserver des embryons excisés.

1. Research Scholar, Germplasm Botanist, Research Associate, and Principal Germplasm Botanist, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh 502 324, India.
2. Professor and Head, Department of Agricultural Engineering, Indian Institute of Technology, Kharagpur 721 302, West Bengal, India.

Molecular and Biochemical Markers for Groundnut Breeding

J.P. Moss[1], Nalini Mallikarjuna[1], W. Powell[2], B.P. Forster[2], R. Waugh[2], P. Lanham[2], and Sarah Fennel[2]

A collaborative ICRISAT/Scottish Crop Research Institute (SCRI) project to develop a molecular map, and to link that to available knowledge on genetics and cytology of *Arachis*, was started in 1990. The major aim was to identify markers for traits not amenable to conventional breeding. A tetraploid $(BxC)^2$ derived from two wild species, *Arachis batizocoi* and *A. chacoense*, was chosen as one of the parents and *A. hypogaea* cv TMV 2, a short season cultivar susceptible to many pests and diseases, as the other parent. The tetraploid derivative, like its parents, has resistance to many important pests and diseases, and was expected to show many molecular polymorphisms compared to *A. hypogaea*. Plants are being grown and hybrids produced at ICRISAT Center. Material is being sent to SCRI for molecular and biochemical analysis.

Arachis DNA has been extracted and purified. Construction of a genomic library of *A. hypogaea* cv TMV 2 has been initiated.

TMV 2 × $(BxC)^2$ DNAs were screened for Random Amplified Polymorphic DNA (RAPD) and a large number of polymorphic markers have been identified. We therefore have 39 genetic markers available for mapping the *Arachis* genome.

Marqueurs moléculaires et biochimiques pour sélection d'arachide

Un projet collaboratif d'ICRISAT/Institut ecossais de recherche sur les cultures (SCRI) vise à mettre au point une carte moléculaire et à la relier aux connaissances disponibles sur la génétique et la cytologie de l'*Arachis*. Ce projet a été entrepris en 1990. Le but essentiel était d'identifier des marqueurs d'aspects qui ne se prêtent pas à une sélection conventionnelle. Un tétraploïde $(BxC)^2$ dérivé de deux espèces sauvages, *Arachis batizocoi* et *A. chacoense*, a été choisi comme l'un des géniteurs et *A. hypogaea* cv TMV 2, cultivar à saison courte, cible de bien des ennemis et maladies comme l'autre géniteur. Le dérivé des tetrapoïdes, comme ses parents, résistait à bien des ennemis et maladies importantes et on prévoyait qu'il manifesterait bien des polymorphismes moléculaires en comparaison avec *A. hypogaea*. Les plants sont en voie de culture et des hybrides ont été produits au centre de l'ICRISAT. Le matériel doit être envoyé au SCRI pour analyse moléculaire et biochimique.

L'ADN d'*Arachis* a été extrait et purifié. La construction d'une bibliothèque génomique d'*A hypogaea* cv TMV 2 a été inaugurée.

L'ADN de TMV 2 × $(BxC)^2$ a été criblé pour l'ADN polymorphique amplifié Aléatoire (RAPD) et un grand nombre de marqueurs polymorphiques ont été identifiés. Nous avons donc 39 marqueurs génétiques disponibles pour cartographier le génome *Arachis*.

1. Principal Cell Biologist and Cell Biologist, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh 502 324, India.

2. Head, Senior Scientists, and Research Associate, Cellular and Molecular Genetics Group, Scottish Crop Research Institute (SCRI), Invergowrie, Dundee DD2 5DA, U.K.

Monoclonal Antibody-based Competitive Enzyme-linked Immunosorbent Assay of Aflatoxin B_1 in Groundnut

N. Ramakrishna[1], V.K. Mehan[1], A.A.G. Candlish[2], D.H. Smith[1], and D. McDonald[1]

Sandwich-type and capture-type competitive enzyme-linked immunosorbent assays (ELISAs) were optimized for the determination of aflatoxin B_1 in groundnut utilizing a specific monoclonal antibody (McAb) developed at the University of Strathclyde. The McAb was conjugated to horseradish peroxidase (HRP) for capture-type assay, while a commercially available goat-antimouse IgG–HRP conjugate was employed for sandwich-type competitive ELISA. Both ELISAs could detect levels of aflatoxin B_1 as low as 20 pg $well^{-1}$. Acetonitrile-water (55 + 45 v/v)–KCl (0.5% w/v) extracts of groundnuts were assayed directly by ELISA after diluting 1:10 with PBS–Tween buffer. The mean toxin recoveries from groundnuts spiked with 10 to 60 $\mu g\ kg^{-1}$ pure aflatoxin B_1 were >90%. The mean within-assay, interassay, and subsample coefficients of variation by ELISA of aflatoxin B_1 in naturally contaminated groundnuts were up to 12%. Although capture-type competitive ELISA is more rapid than sandwich-type, it is more expensive.

L'aflatoxine B_1 chez l'arachide: titrage immunosorbant Elisa compétitif, sur la base d'anticorps monoclonal

Des titrages immunosorbants liés aux enzymes du type sandwich et du type saisie ont été portés à l'optimum pour la détermination de l'aflatoxine B_1 chez l'arachide, au moyen d'un anticorps monoclonal spécifique (McAb) développé à l'Université de Strathclyde. Le McAb a été conjugué à la péroxydase de raifort (HRP) pour titrage du type saisie, tandis qu'un conjugué IgG-HRP dans le caprin anti-souris disponible dans le commerce a servi à un ELISA compétitif du type sandwich. Les deux ELISAs pouvaient dépister des niveaux d'aflatoxine B_1 aussi faibles que 20 pg $well^{-1}$, dans l'acétonitrile-eau (55 + 45 v/v) -KCl (0,5% w/v) des extraits d'arachide étant titrés directement par l'ELISA après dilution à 1:10 après tampon PBS twin. Les principales reprises de toxine des arachides enrichies à 10 à 60 $\mu g\ kg^{-1}$ d'aflatoxine pure B_1 était >90%. Les coefficients moyens intratritral, intertitral et sub échantillon de variation par ELISA de l'aflatoxine B_1 dans des arachides contaminées naturellement allaient jusqu'à 12% Bien que l'ELISA compétitive du type saisie soit plus rapide que le type sandwich, elle est plus coûteuse.

1. Research Associate, Plant Pathologist, Principal Plant Pathologist, and Program Director (Legumes), International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh 502 324, India.

2. Research Scientist, Rhône-Poulenc Diagnostics Ltd., Glasgow G1 1YT, U.K.

Germline Transformation of Legumes Mediated by Electric Discharge Particle Gun

G.S. Brar, D.E. McCabe, D.R. Russell, P. Christou, and W.F. Swain[1]

Commercially useful genetic engineering of crop plants requires an efficient, reproducible and genotype-independent transformation system, elite germplasm, and the availability of genes determining valuable agronomic traits. The transformation of major legume crops such as soybean (*Glycine max*), common bean (*Phaseolus vulgaris*), pea (*Pisum sativum*), cowpea (*Vigna unguiculata*), alfalfa (*Medicago sativa*), lentil (*Lens culinaris*), and clover (*Trifolium* spp) has met with various degrees of success in the past few years. We have been successful in developing a commercially viable transformation system for soybeans and *Phaseolus* that meets all of the above criteria. In this method, 1-3 µm gold beads are coated with the exogenous DNA and are accelerated into cells of target tissues, preferably apical or axillary meristems of mature or immature seeds. The bombarded tissues are manipulated to produce multiple shoots that are screened for the reporter gene (GUS). Transformed plants are transferred to the greenhouse to produce transgenic seeds. By using these procedures, we have transferred genes for resistance to Bialaphos and other herbicides into elite soybean cultivars. These plants currently are in field trials. In *Phaseolus*, plants engineered for herbicide (Bialaphos) or virus (BGMV) resistance have also been developed using the same protocol. Efforts are underway to investigate whether procedures used for soybeans and *Phaseolus* transformation are adaptable to groundnut transformation.

Transformation de ligne de germe de légumineuses médiatées par pistolets à particules à charges électriques

Une manipulation génétique commercialement utile de plants cultivés exige un système de transformation efficace, reproductible et indépendant du génotype, des ressources génétiques élites et la disponibilité de gènes déterminant des traits agronomiques de valeur. La transformation de principales cultures légumineuses comme le soja (*Glycine max*), le haricot (*Phaseolus vulgaris*), le pois (*Pisum sativum*), le niébé (*Vigna unguiculata*), l'alfa (*Medicago sativa*), la lentille (*Lens culinaris*), et le trèfle (*Trifolium* spp) a obtenu un degré divers de succès depuis quelques années. Nous avons réussi à développer un système de transformation commercialement viable pour le soja et le *Phaseolus*, qui répond à tous les critères ci-dessus. Par cette méthode, 1-3 µm de billes d'or sont revêtues d'ADN exogène et sont accélérées en cellules de tissu cible, de préférence des méristèmes apicaux ou axillaires de semences matures ou immatures. Les tissus bombardés sont manipulés pour produire des pousses multiples qui sont criblées pour le gène porteur (GUS). Les plants transformés sont transférés à la serre pour produire des semences transgéniques. En utilisant ces méthodes, nous avons transféré des gènes pour la résistance au Bialaphos et d'autres herbicides en cultivar de soja d'élite. Ces plants sont actuellement aux essais sur le terrain. Dans le cas du *Phaseolus* , des plants manipulés pour la résistance à l'herbicide (Bialaphos) ou au virus (BGMV) ont également été développés au moyen du même protocole. Des efforts sont entrepris pour enquêter si les procédures utilisées pour la transformation des sojas et du *Phaseolus* sont adaptables à la transformation de l'arachide.

1. Research Geneticist, Research Fellow, Senior Molecular Biologist, Senior Research Scientist, and Senior Molecular Biologist, Agracetus Inc., 8520 University Green, Middleton, WI 53562, USA.

Breeding

Heterosis in Intervarietal Crosses of Groundnut

V. Manoharan and S. Thangavelu[1]

Six ovule parents, TMV 2, TMV 7, TMV 9, TMV 12, Co 1, and J 11 (spanish bunch), and three pollen parents, Gangapuri, EC 21137-1 (valencia), and Robut 33-1 (virginia), were crossed in a line × tester-mating design. The 18 F_1 hybrids and their 9 parents were grown in a randomized block design with three replications. At maturity, observations were recorded on plant height, number of mature pods, 100-pod mass, shelling percentage, 100-kernel mass, and pod yield. Heterosis and heterobeltiosis were estimated. All the hybrids involving the valencia genotypes showed significant positive heterobeltiosis for plant height. The hybrids TMV 7 × Robut 33-1 and TMV 9 × Robut 33-1 exhibited significant positive heterobeltiosis for pod yield. These hybrids also expressed heterobeltiosis in the desirable direction for other yield attributes, number of pods, 100-pod mass, and kernel mass. Co 1 × EC 21137-1 alone showed positive heterobeltiosis for shelling percentage while negative values were estimated for most of the crosses for this trait. The spanish × virginia crosses expressed greater average heterobeltiosis for pod yield and its attributes than the spanish × valencia crosses. Hence intersubspecific hybridization would be more beneficial for improvement of yield and its attributes in groundnut than intra-subspecific hybridization.

Hétérosis dans les hybrides intervariétaux d'arachide

Six géniteurs femelles, à savoir TMV 2, TMV 7, TMV 9, TMV 12, Co 1 et J 11 (buissonnant spanish) et trois parents mâles, à savoir Gangapuri, EC 21137-1 (valencia), et Robut 33-1 (virginia) ont fourni des hybrides dans une lignée × dispositif d'accouplement de testeur. Les dix-huit hybrides F1 et leurs neuf parents ont été cultivés dans un dispositif de parcelles aléatoires avec trois répétitions. A la maturité, on notait des observations sur la hauteur de plants, le nombre de gousses matures, la masse de 100 gousses, le pourcentage d'écossage, la masse de 100 grains et le rendement en gousses. L'hétérosis et l'hétérobeltiose ont été estimées. Tous les hybrides comportant le génotype valencia révélaient une hétérobeltiose positive significative pour la hauteur des plants. Les hybrides TMV 7 × Robut 33-1 and TMV 9 × Robut 33-1 manifestaient une hétérobeltiose positive significative pour le rendement en gousses. Ces hybrides manifestaient aussi des hétérobeltioses dans la direction désirable pour d'autres attributs de rendement, le nombre des gousses, la masse de 100 gousses et la masse de grains. Co 1 × EC 2137-1 seul manifestait une hétérobeltiose positive pour le pourcentage d'écossage, tandis que des valeurs négatives étaient estimées pour la plupart des hybrides pour ce trait. Les hybrides spanish × virgina exprimaient une plus grande moyenne d'hétérobeltiose pour le rendement en gousse et ses attributs que les spanish × valencia. Donc, l'hybridation inter-subspécifique serait plus bénéfique pour l'amélioration du rendement chez l'arachide que l'hybridation intra-subspécifique.

1. Assistant Professor (Breeding) and Professor and Head, Regional Research Station, Vridhachalam, Tamil Nadu 606 001, India.

Groundnut Varietal Improvement

Liao Boshou, Wang Yuying, Duan Laixiong, and Tan Yujun[1]

The progress of the research done in the Oil Crops Research Institute (OCRI) during the past 10 years are outlined below.

Over 4000 groundnut germplasm accessions have been collected and evaluated for National Genebank Registration. From the evaluation, some Chinese local lines of groundnut have been recently identified as bacterial wilt (*Pseudomonas solanacearum*) resistant. Many lines resistant to foliar diseases have been introduced from ICRISAT and used in breeding programs. About 100 *Arachis* spp accessions have been introduced and research initiated to transfer resistances. An early-maturing cultivar, Ehua 4, was released in 1987.

A bacterial wilt-resistant cultivar, Zhonghua, was released in 1990. A rust (*Puccinia arachidis*)-resistant cultivar, Zhonghua 117, will be released soon. Inheritance of resistances in groundnut to bacterial wilt and to rust have been investigated. Screening for aflatoxin resistance and genetic evaluation for N-fixation are underway.

Amélioration variétale de l'arachide

Les progrès de la recherche effectuée à l'Institut de la recherche sur les plantes oléagineuses (OCRI) pendant les 10 dernières années sont résumés ci-dessous:

Plus de 4 000 obtentions de ressources génétiques d'arachide ont été collectées et évaluées pour l'enregistrement national de la banque de gènes. D'après l'évaluation, certaines lignées chinoises locales d'arachide ont été récemment identifiées comme résistant au flétrissement bactérien (*Pseudomonas solanacearum*). Bien des lignées résistantes aux maladies foliaires ont été introduites de l'ICRISAT et servent à des programmes de sélection. Environ 100 obtentions d'*Arachis* ont été introduites et des recherches ont été entreprises pour transférer les résistances. Un cultivar à maturation précoce — Ehua 4, a été vulgarisé en 1987.

Un cultivar Zhonghua résistant au flétrissement bactérien a été vulgarisé en 1990. Un cultivar Zhonghua 117 résistant à la rouille (*Puccinia arachidis)* sera vulgarisé sans tarder. L'héritage de résistance chez l'arachide au flétrissement bactérien et à la rouille a été étudié. Nous avons entrepris le criblage pour la résistance à l'aflatoxine et une évaluation génétique pour la fixation nitrique.

1. Assistant Professor and Associate Professors, Oil Crops Research Institute, Chinese Academy of Agricultural Sciences (CAAS), Wuhan, Hubei Province, People's Republic of China.

Groundnut Ideotypes and Breeding Strategies for the Humid Zone of Cameroon

N.B. Essomba[1]

Groundnut is an important food and cash crop in Cameroon. The Humid Zone (annual rainfall 1500 mm) is responsible for 67% of the country's production, but until recently has had no coordinated research program. Plant breeding is one of the key elements in the groundnut program for this zone at the Institute of Agricultural Research (IRA). Five research domains based on physical environmental factors and plant growth factors have been identified. Desirable traits were identified using available information on cropping systems, crop utilization, and production and other constraints. Ideotypes have been defined for each research domain. The program comprises two components: germplasm management and comparative variety trials. Short-term aims are to collect and characterize local varieties. Exotic germplasm will be added to increase local variability. The priority traits are adaptability, stability of yield, resistance to disease, tolerance to pests, and dormancy. Breeding trials will seek to identify varieties exhibiting these traits, with a view to the early release of higher-yielding cultivars. Long-term work will involve hybridization to combine these priority traits. At this stage other traits will be included, for example nitrogen-fixing ability, protein content, and oil content. The aim is to produce varieties better suited to the environment and more acceptable for their end-use.

Idéotypes d'arachide et stratégies de sélection pour la zone humide du Cameroun

L'arachide est une culture alimentaire et de rente importante pour le Cameroun. La zone humide (pluviosité annuelle 1500mm) fournit 67% de la production du pays, mais récemment encore il n'y avait aucun programme de recherche coordonnée. La sélection des plantes est l'un des éléments clef du programme arachidier pour cette zone à l'Institut de recherche agricole (IRA). Cinq domaines de recherche basée sur des facteurs physiques de l'environnement et des facteurs de croissance des plantes ont été identifiés. Des traits désirables ont été identifiés en se servant des informations disponibles sur les systèmes de culture/l'utilisation des récoltes et la production et d'autres contraintes. Des idéotypes ont été définis pour chaque domaine de recherche. Le programme comporte deux éléments: gestion des ressources génétiques et essai variéto-comparatif. Les buts à court terme consistent à collecter et à caractériser des variétés locales. Les ressources génétiques exotiques seront ajoutées pour accroître la variabilité locale. Les traits prioritaires sont l'adaptabilité, la stabilité du rendement, la résistance aux maladies, la tolérance aux ennemis et la dormance. Des essais de sélection chercheront à identifier les variétés qui manifestent ces traits, en vue de vulgariser sans tarder des cultivars à plus fort rendement. Le travail à long terme comportera l'hybridation pour combiner ces traits prioritaires. A cette étape d'autres traits seront ajoutés, par exemple l'aptitude à fixer l'azote, la teneur protéique, et la teneur en huile. Le but est de produire des variétés qui conviennent mieux à l'environnement et qui sont plus acceptables pour leur usage final.

1. Research Officer, Institute of Agrcultural Research, Nkolbisson Centre, P.O. Box 2067 Yaounde, Cameroon.

Transposon-induced Mutants of Taxonomical Importance in Groundnut

M.V.C. Gowda and H.L. Nadaf[1]

A genetically stable line, Dharwad Early Runner, upon treatment with 0.20% ethylmethane sulfonate has given rise to mutants that resemble botanical types, namely spanish bunch and valencia belonging to subsp *fastigiata*, and virginia bunch and virginia runner belonging to subsp *hypogaea*. A critical analysis of these mutants has indicated existence of all the morphological features that are used in differentiating the botanical groups. Further analysis on nature of origin and behavior of mutants revealed the possible involvement of transposons in their induction. This is evident by the occurrence of reversion, germinal segregation, and allelic forms.

These mutants will be useful in generating definite information on the genetic basis of infraspecific differentiation in groundnut. To our knowledge this is the first report on the existence of transposons in groundnut. The transposons could be an important tool in genetic dissection of groundnut through induction of a great array of mutants and gene tagging in future.

We give a morphological description of parents and the mutants, data and photographs pertaining to reversion, generative segregation, and occurrence of allelic forms.

Mutants induits par transposons d'importance taxonomique chez l'arachide

Une lignée génétiquement stable, Dharwad rampant précoce, après traitement à 0,20% de sulphonate d'éthylméthane, a fourni des mutants qui ressemblent aux types botaniques, à savoir le spanish buissonnant et le valencia, appartenant à la sous-espèce *fastigiata* et un buissonnant virginia et un type virginia rampant appartenant à la sous-espèce *hypogaea*. Une analyse critique de mutants a indiqué l'existence de tous les aspects morphologiques qui servent à différencier les groupes botaniques. Une analyse plus poussée sur la nature de l'origine et le comportement de mutants a révélé l'implication possible de tranposons dans leur induction. Cela est manifesté par l'apparition de réversion, la ségrégation germinale et des formes alléliques.

Ces mutants seront utiles pour fournir des informations claires sur la base génétique de la différenciation intraspécifique chez l'arachide. Autant que nous le sachions, c'est le premier rapport de transposons chez le mutant dans l'arachide. Les tranposons pourraient être un outil important pour la dissection génétique de l'arachide par l'induction d'une grande gamme de mutants et le marquage de gènes à l'avenir.

Nous donnons une description morphologique des parents et des mutants, avec des données et des photographies relatives à la réversion, à la ségrégation générative et l'apparition de formes alléliques.

1. Associate Professors of Genetics and Plant Breeding, University of Agricultural Sciences, Dharwad 580 005, Karnataka, India.

Varietal Improvement of Virginia Runner Groundnut in Karnataka

K. Giri Raj and H.L. Nadaf[1]

In Alfisols and scanty rainfall tracts of Karnataka, traditional spanish bunch (SB) groundnut area is being replaced by virginia runner (VR) types mainly because of their tolerance to drought, pests, and diseases, besides yielding abundant quality fodder. A number of high-yielding SB groundnut varieties are already under cultivation during the rainy and postrainy/summer seasons but the situation in the VR group is characterized by nonavailability of suitable high-yielding cultivars. Although a few cultivars, Pondicherry 8, BH 8-18, and, more recently, S 230, were recommended for cultivation, they are not popular because of their low productivity potential. However, efforts have been made recently to develop and identify high-yielding cultivars at the Agricultural Research Station, University of Agricultural Sciences, Sankeshwar, Dharwad. In the process of identifying superior cultivars, CSMG 15 and ICGS 76 were found to be superior virginia bunch (VB) cultivars. However, these VB cultivars do not meet the local demands for quality fodder obtained from VR cultivars.

Recently, a selection from local VR type (Mardur local) has been found to be promising for high pod yield (2.44 t ha^{-1}) with 93.6% superiority over control S 230 as well as national control M 13. In addition, it possesses desirable pod and kernel features with a better shelling percentage of about 70%, and high biomass production valued for its nutritious cattle feed. Efforts are also being made to combine high pod yield with high oil content, coupled with resistance to major diseases and pests by the pedigree-bulk breeding method.

Amélioration variétale de l'arachide virginia rampante au Karnataka

Dans les zones d'alfisol et des terrains à faible pluviosité du Karnataka, les plantations d'arachide buissonnant spanish (SB) sont en voie de remplacement par des types rampants virginia (VR), surtout en raison de leur tolérance à la sécheresse, aux ennemis et aux maladies, outre le fait qu'elles fournissent un fourrage abondant de qualité . Une certain nombre de variétés d'arachide SB à fort rendement sont déjà en culture pendant la saison des pluies et la saison d'été/post pluies, mais la situation du groupe VR est caractérisée par l'absence de cultivars à haut rendement qui conviennent. Bien que peu de cultivars, Pondicherry 8, BH 8-18, et plus récemment S 230 aient été recommandés pour la culture, ils ne sont pas populaires en raison de leur faible potentiel de productivité. Toutefois, des efforts ont été faits récemment pour développer et identifier des cultivars à haut rendement à la station de recherches agricoles de l'Université des sciences agricoles à Sankeshwar, Dharwad. Dans le processus d'identification de cultivars supérieurs, on a constaté que CSMG 15 et ICGS 76 sont des virginias buissonnants (VB) supérieurs. Toutefois ces cultivars VB ne répondent pas à la demande locale de fourrage de qualité fournis par les cultivars VR.

Récemment, une sélection du type VR local (Mardur local) a révélé promettre un rendement en gousses élevé (2.44 t ha^{-1}), avec une supériorité de 93.6% par rapport au témoin S230, ainsi qu'au contrôle témoin national M 13. En outre, ce type possèdes des aspects désirables pour la gousse et pour le grain, avec un pourcentage d'environ 70% de plus d'écossage et une production de biomasse élevée, appréciée pour sa valeur nutritive d'affouragement des bovins. Des efforts sont actuellement entrepris aussi pour combiner un rendement élevé en gousses avec une forte teneur en huile, joint à une résistance aux principales maladies et aux principaux ennemis par la méthode de sélection massale.

1. Senior Scientist (Oilseeds) and Junior Breeder (Groundnut), Oilseeds Project, University of Agricultural Sciences, Dharwad 580 005, Karnataka, India.

Inheritance of Some Quality Characters of Groundnut

Y. Shanlin, M. Ping, and L. Wenqi[1]

Seeds of three varieties of groundnut were irradiated with gamma rays giving three mutants of white-vein with smaller leaflets (WVSL) than the parents. Populations derived from WVSL segregated into three kinds of phenotypes: 1) those like the initial parent, 2) the same as WVSL, and 3) the same as WVSL in vein color but smallest in stature with small leaflets and fruit of the three. The population segregated into a 1:2:1 ratio for normal:smaller:smallest in size of leaflets, a 3:1 ratio for high:low stature, and a 1:3 ratio for yellow:white veins. The character of plant height showed dominance, white-veins had reversed dominance, and size of the leaflets had partial dominance controlled by the same locus. The gene symbol *Mm* is proposed for the independent locus controlling the leaflets, height of the plants, and color of the veins. Chlorophyll content of the leaflets seems to have no relation to the color of the veins.

Hérédité de certains caractères de qualité de l'arachide

Des semences de trois variétés d'arachide ont été irradiées aux rayons gamma, fournissant trois mutants à veinures blanches et folioles plus petites(WVSL) que dans le cas des parents. Les populations dérivées de WVSL ségréguées en trois genres de phénotypes: 1) ceux qui ressemblaient aux parents initiaux, 2) les mêmes que WVSL, et 3) les mêmes que WVSL quant à la couleur des veinures mais d'une stature plus petite, avec les folioles et les fruits les plus petits des trois. La population ségréguée selon un ratio de 1:2:1 pour les normaux:petits:plus petits quant à la dimension des folioles, et un ratio de 3:1 pour stature haute:petite, et un ratio de 1:3 pour les veinures jaune:blanches. Les caractéristiques de la hauteur des plants révélaient une dominance, les veinures blanches une dominance inverse, et la dimension des folioles une dominance partielle contrôlée par le même locus. Le symbole de gènes *Mm* est proposé pour le locus indépendant qui déterminait les folioles, la hauteur des plants et la couleur des veinures. La teneur en chlorophylle des folioles ne semblait pas présenter de rapport avec la couleur des veinures.

1. Vice Director and Groundnut Breeder, Research Geneticist, and Research Assistant, Shandong Peanut Research Institute, Laixi City, Shandong Province, People's Republic of China.

Breeding Early-maturing Groundnuts at ICRISAT

H.D. Upadhyaya[1], S.N. Nigam[1], and M.J. Vasudeva Rao[2]

Early-maturing high-yielding cultivars of groundnut are required for areas where the growing season is short and/or end-of-season drought or early frosts are frequent. They also form an important component of high-intensity cropping systems in many countries. Using diverse sources of earliness, we have developed several early-maturing high-yielding varieties that have performed exceedingly well in many countries. ICGV 86015 in Nepal, Niger, and Vietnam; ICGV 86055 in India; ICGV 86061 in Malawi; ICGV 86062 in Guinea; and ICGV 86092 in Benin have yielded significantly more than the local controls.

A modified pedigree method is used to advance generations. All segregating populations are harvested at 1470°Cd cumulative thermal time (CTT), which is equivalent to 90 days of rainy season at Patancheru. In replicated yield trials at Patancheru, each line is evaluated for mature pod yield at 1240°Cd CTT (equivalent to 75 days of rainy season at Patancheru) and 1470°Cd CTT for two seasons. In addition to pod yield at 1240° and 1470°Cd CTT, the percentage yield difference between these two harvest dates is also taken into account to identify extra-early-maturing genotypes. Selected superior lines are entered in a multilocational testing program.

Efforts are being made to identify additional sources of earliness. Studies on inheritance of earliness and related traits are in progress to further refine the selection procedure.

Sélection d'arachides à maturation précoce à l'ICRISAT

Des cultivars d'arachide à maturation précoce et à haut rendement sont nécessaires dans les zones où la saison de croissance est courte et/ou la sécheresse en fin de campagne ou des gels précoces sont fréquents. Cela représente également un élément important de système de culture à forte intensité de bien des pays. Au moyen de diverses sources de précocité, nous avons mis au point plusieurs variétés précoces et à haut rendement qui ont donné des résultats remarquablement satisfaisants dans bien des pays. IGCV 86015 au Népal, au Niger et au Vietnam; ICGV 86055 en Inde; ICGV 86061 au Malawi; ICGV 86062 en République de Guinée; et ICGV 86092 au Bénin ont donné des résultats nettement meilleurs que ceux des témoins locaux.

Une méthode de pédigrée modifiée est utilisée pour faire avancer les générations. Toutes les populations ségrégantes sont récoltées à 1470°Cd de temps thermal cumulatif (CTT) qui est équivalent à 90 jours de saison des pluies à Patancheru. Dans des essais de rendement répétés à Patancheru, chaque lignée était évaluée pour le rendement en gousses matures à 1240°Cd CTT (équivalent à 75 jours de saison des pluies à Patancheru) et 1470°Cd CTT pour deux campagnes. Outre le rendement en gousses à 1240°Cd CTT et 1470 Cd CTT les différences de pourcentage de rendement entre ces deux dates de récolte ont été également prises en considération pour identifier les génotypes à maturation extra-précoce. Les lignées supérieures sélectionnées sont inscrites dans le programme de tests multilocaux.

Des efforts ont été entrepris pour identifier des sources additionnelles de précocité. Des études sur l'héritabilité de précocité et des traits apparentés sont en train pour raffiner davantage le procédé de sélection.

1. Plant Breeder and Principal Plant Breeder, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh 502 324, India.

2. Plant Breeder, formerly ICRISAT, Now at: ICI India Limited, Bangalore 560 068, Karnataka, India.

On the Problem of Groundnut Breeding for Early Maturity

D.I. Obydalo[1]

The problem of developing early-maturing groundnut cultivars is common to all groundnut growing countries. Efficiency of breeding genotypes for short growing periods depends on our knowledge about specific biological features of groundnut plants growing all over the world to give possibilities for selecting early-maturing forms. Studies have indicated that the sowing to emergence period in groundnut is conditioned primarily by soil temperature whereas duration of other phases of plant growth is cultivar specific. The development of an early-maturity high-yielding cultivar, Krasnodarets 13, has facilitated the introduction of groundnut crop in the North Caucasus region, located at 45°N.

Sur le problème de la sélection de l'arachide pour maturité précoce

Le problème de mettre au point des cultivars d'arachide à maturité précoce se présente dans tous les pays producteurs d'arachide. L'efficacité de la sélection de génotypes pour période de croissance courte dépend de notre connaissance sur les aspects biologiques spécifiques des plants d'arachide qui poussent dans le monde entier pour donner des possibilités de sélectionner des formes à maturation précoce. Des études ont montré que la période entre le semis et la levée de l'arachide est déterminée surtout par la température du sol, tandis que la durée des autres phases de la croissance du plant dépend du cultivar. Le développement d'un cultivar très précoce et à haut rendement, le Krasnodarets 13, a facilité l'introduction de la culture de l'arachide dans la région du nord-Caucase, situé à 45° nord.

1. Groundnut Breeder and Head, Groundnut Breeding Laboratory, V.S. Pustovoit All-Union Research Institute for Oil Crops (VNIIMK), Ul. Filatova 17, 350038 Krasnodar, CIS (formerly USSR).

Performance of Short-duration Groundnut Lines Suitable to Increase Cropping Intensity in Rainfed Areas of Pakistan

Naazar Ali and Shah Nawaz Malik[1]

Development and selection of short-duration varieties of groundnut, to fit into the existing cropping pattern and allow double cropping with wheat, is one of the major objectives in Pakistan. A replicated trial with 15 early lines (received from ICRISAT) and a local control (Banki) was conducted for 2 years at the National Agricultural Research Centre, Islamabad. The results for adaptability and yield performance of the early lines were very encouraging. On an average of 2 years, six lines, ICGS(E) 56, ICGS(E) 52, JL 24, Robut 33-1, ICGS(E)131, and L 40, exceeded the local control for dry pod yield, 100-kernel mass, and shelling percentage. Maximum pod length was shown by Banki but the quality of the seed was poor due to immature and shrivelled kernels. Two promising lines, ICGS(E) 52 and ICGS(E) 56, have been included in advanced yield tests and are being considered for release in rainfed areas. With the introduction of these short-duration varieties, the risk of drought stress during May–June will be covered. In addition, the area under groundnut will also increase resulting in an increase in groundnut production.

Comportement de lignées d'arachide à cycle court, convenant à l'augmentation de l'intensité de la culture dans les zones pluviales du Pakistan

Le développement et la sélection de variétés d'arachide à cycle court, pouvant s'adapter au régime de culture existant et permettre une double récolte avec le blé, c'est là l'un des principaux objectifs du Pakistan. Un essai à répétitions portant sur 15 lignées précoces (reçues de l'ICRISAT) et un témoin local (Banki) ont été effectuées pendant deux ans au Centre national de recherche agricole à Islamabad. Les résultats quant à l'adaptabilité et au rendement des lignées précoces ont été très encourageants. Pendant une moyenne de 2 ans, 6 lignées ICGS(E) 56, ICGS(E) 52, JL 24, Robut 33-1, ICGS(E) 131, et L 40 ont dépassé le témoin local du point de vue de la production de gousses sèches, de la masse de 100 grains et du pourcentage d'écossage. La variété banki avait la longueur maximum de gousse mais la qualité de sa semence était faible, en raison de grains immatures et ridés. Deux lignées qui semblent promettre, ICGE(E) 52 et ICGS(E) 56, ont figuré dans des tests de rendement plus poussés et on envisage de les vulgariser dans des zones à culture pluviale. Dans le cas de l'introduction de ces variétés à cycle court, il faut envisager le risque d'un stress hydrique pendant mai et juin. En outre, les terrains cultivés d'arachide seront aussi accrus, en vue d'une augmentation de la production arachidière.

1. Principal Scientific Officer (Oilseeds) and Scientific Officer (BARD), National Agricultural Research Centre, Islamabad, Pakistan.

More Slim, More Early, and More Yield "Subsp *fastigiata* Effects": Agro-physiological Basis for the Ideotype of Groundnut Cultivars

K. Maeda[1]

The hardest barrier to break the low yield of groundnut cultivars, particularly subsp *fastigiata*, that are widely grown in the semi-arid and humid tropical countries, is their small seed size. To increase the seed size is, therefore, very important in groundnut breeding. However, the following question should also be reinvestigated: "Is the distribution ratio of dry matter to stem system appropriate or not to maximize the seed yield?". The stem system has no role in supporting groundnut 'physically', of which the fruits as a big sink grow underground. In this study, the author emphasizes a concept to raise the yield of groundnut based on the field trials conducted by use of local cultivars, subsp *hypogaea*, and the Norin cultivars that were developed by single or multiple hybridization between the local and introduced cultivars of subsp *hypogaea* and subsp fastigiata, since the mid 1950s in Japan. The author adopts a plant parameter, "seed dry weight/stem dry weight ratio", which has been adopted into breeding high-yielding soybean cultivars in Japan. This concept is useful in analyzing the relationship between dry matter distribution to the stem system and yield in groundnut.

In Japan, erect growth habit and earliness in flowering and maturation are agronomically required for adoption of groundnut into cropping systems. Large seeds are also essential for groundnut use as snacks and confectioneries in diversified forms. Earliness, large seeds, and higher "seed/stem ratio" and harvest index, which were realized by decrease of the number of branches, and the high seed yield more than 3 t ha^{-1}, on average, were achieved by some of the recently released Norin cultivars. The author called them the "subsp *fastigiata* effects", and presented data showing its agrophysiological basis on the "ideotype" of groundnut, with an example of high yields in field trials.

Plus mince, plus précoce, et plus de rendement "Effets de la sous-espèce *fastigiata*": Base agro-physiologique pour l'idéotype de cultivars d'arachide

La barrière la plus difficile à franchir pour surmonter le faible rendement des cultivars d'arachide, particulièrement de la sous-espèce *fastigiata*, qui sont cultivés largement dans les pays tropicaux semi-arides et arides, c'est la petite dimension de leur semence. Il est donc très important pour la sélection arachidière d'augmenter la dimension des grains. Toutefois, il faut réexaminer la question suivante: "Le ratio de répartition de la matière sèche et du système de tige est-il approprié ou non pour porter le rendement en semence au maximum ?" Le système de tige n'a aucun rôle d'appui de l'arachide physiquement, les fruits représentant une masse qui croît sous le sol. Dans cette étude, l'auteur souligne un concept pour augmenter le rendement de l'arachide sur la base des essais effectués sur le terrain au moyen des cultivars locaux, de la sous-espèce *hypogaea*, et de cultivars Norin qui ont été développés par hybridation simple ou multiple entre les cultivars locaux et introduits de la sous-espèce *hypogaea* et de la sous-espèce *fastigiata*, ces travaux ayant été effectués depuis l'année 1950 au Japon. L'auteur adopte un paramètre de plant, avec "un ratio poids sec de semence/poids sec de tige", qui a été adopté au Japon pour la sélection de cultivars de soja à haut rendement. Ce concept est utile pour analyser le rapport entre l'attribution de matière sèche au système de tige et le rendement en arachide.

1. Professor, Faculty of Agriculture, Kochi University, Monabe, Nankoku, Kochi, 738, Japan.

Au Japon, l'adoption d'arachide dans les systèmes de culture exige un port érigé et la précocité de la floraison et de la maturation. Les gros grains sont également essentiels pour l'usage d'arachide comme casse-croûte et pour la confiserie sous des formes diversifiées. La précocité des gros grains, le "ratio semence/tige" et l'indice de récolte qui ont été obtenus en réduisant le nombre de branches, et le rendement élevé en semence de plus de 3 tonnes par hectare, en moyenne, ont été obtenus par certains des cultivars Norin récemment vulgarisés. L'auteur les appelle "les effets de la sous-espèce *fastigiata*", et a présenté des données qui montrent sa base agrophysiologique sur "l'idétotype" de l'arachide, avec un exemple de rendement dans les essais sur le terrain.

Genetic Manipulation of Canopy to Achieve Yield Advancement in Groundnut

M.V.R. Prasad[1] and G.V.S. Nagabhushanam[2]

Investigations on genetic restructuring of groundnut have indicated that sequential branching types (spanish and valencia) do not tolerate any reduction in the canopy development. It was observed that all the spanish and valencia mutants with higher pod numbers exhibited enhanced canopy development. However, with respect to alternate branching virginia genotypes, it was possible to combine a compact canopy frame and higher reproductive efficiency. Among the wide range of characters studied, it was observed that canopy diameter and nodule mass at 60 days were the most stable attributes having a direct positive association with kernel yield, unlike pod yield, an unstable character. The wide range of groundnut genotypes were categorized into four distinct canopy types: most compact (category 1), medium compact (category 2), medium spreading (category 3), and most spreading (category 4). It was revealed that higher levels of stability for kernel yield were associated with the intermediate canopy types, i.e., categories 2 and 3.

Canopy compaction in groundnut from type 4 to 1 marked a shift from alternate to sequential branching types. The crosses involving category 2 and category 3 canopy types exhibited perceptibly high positive heterosis in F_1 and high means and large variances in the segregating generations for several agronomic attributes. A choice of appropriate parents of intermediate canopy types and selection of canopy development in the later generations are likely to result in agronomically superior genotypes.

Manipulation de la canopie pour parvenir à accroître le rendement de l'arachide

Des enquêtes sur la restructuration génétique de l'arachide ont indiqué que les types à embranchement séquentiel (spanish et valencia) ne tolèrent aucune réduction du développement de la canopie. On a remarqué que tous les mutants spanish et valencia qui ont un nombre de gousses supérieur manifestent une augmentation du développement de la canopie. Toutefois, en ce qui concerne les génotypes virginia à ramification alterne, il a été possible de combiner une canopie compacte et une efficacité supérieure de la reproduction. Parmi la vaste gamme de caractéristiques étudiées, on a remarqué que le diamètre de la canopie et la masse nodulaire à 60 jours étaient les aspects les plus stables, ayant une corrélation positive directe avec le rendement en grain, contrairement au rendement en gousse qui est une caractéristique instable. La vaste gamme de génotypes d'arachide a été classée en quatre types distincts de canopie: le plus compact (catégorie 1), la compaction moyenne (catégorie 2), buissonneuse moyen (catégorie 3) et le plus grand buissonneuse (catégorie 4). On a pu voir que les niveaux les plus élevés de stabilité en ce qui concerne les rendements en grains étaient associés aux types intermédiaires, canopie, c'est-à-dire aux catégories 2 et 3.

La compaction de la canopie chez l'arachide, du type 4 au type 1, indiquait un glissement des types à embranchements alternes ou séquentiels. Les hybrides comportant les types canopie des catégories 2 et 3 manifestaient une hétérose positive nettement élevée dans F_1 et des moyennes élevées et une grande variance des générations ségrégantes quant à plusieurs aspects agronomiques. Un choix de parents appropriés de type canopie intermédiaire et la sélection d'un développement de la canopie dans les générations ultérieures fournira probablement des génotypes agonomiquement supérieurs.

1. Principal Scientist, Directorate of Oilseeds Research, Hyderabad 500 030, India.

2. Research Associate, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh 502 324, India.

Groundnut Breeding for Shade Tolerance

R.M. Abilay, M.H. Magpantay, and L.A. Lantican[1]

Large marginal areas in Asia could be utilized for groundnut production. In the Philippines alone, there are more than 8 million hectares grown to coconut (*Cocos nucifera*), corn (*Zea mays*), and sugarcane (*Saccharum officinarum*). These vast tracts of land are potential areas for intercropping groundnuts under coconut, or with corn/sugarcane. Understorey growing often results in marked yield reduction because the main crop (coconut/corn/sugar-cane) partially shades the groundnut. Hence, shade-tolerant cultivars should be developed.

The Peanut CRSP is supporting research on shade tolerance at the University of the Philippines at Los Baños in collaboration with North Carolina State University to develop shade-tolerant groundnut lines/cultivars.

Screening of 552 entries under 40 to 58% artificial shade resulted in the identification of some shade-tolerant materials. These were either used as parents in 57 crosses for the development of shade-tolerant lines, or as entries in series of yield trials under coconut.

Six lines/cultivars (IPB Pn 82 80-5, IPB Pn 82 82-85, IPB Pn 82 71-26, IPB Pn 82 71-32, UPL Pn 2, and UPL Pn 8) were identified to be high yielding across locations and seasons. These are currently being evaluated in on-farm trials at Davao, Aurora Province, Bicol, Quezon, and North Cotabato.

IPB Pn 82 68-68 is a very promising shade-tolerant line. It has produced high yield in field trials conducted simultaneously under artificial shade structures (e.g., four shade levels using Saran shade cloths) and natural conditions (e.g., two coconut testing sites) during the 1990/91 dry cropping season.

Sélection de l'arachide pour la tolérance de l'ombrage

De grandes superficies marginales d'Asie pourraient servir à la production arachidière. Mais rien qu'aux Philippines, il y a plus de 8 millions d'hectares consacrés au cocotier (*Cocos nucifera*), au maïs (*Zea mays*), et à la canne à sucre (*Saccharum officinarum*). Ces vastes terrains sont des zones potentielles de culture associée d'arachide sous cocotier ou de maïs/canne à sucre. La culture sous ombrage provoque souvent une réduction marquée du rendement, parce que la récolte principale (cocotier/maïs/canne à sucre) ombrage partiellement l'arachide. C'est pourquoi des cultivars qui tolèrent l'ombre devraient être mis au point.

Le groupe Peanut CRSP appuie une recherche sur la tolérance de l'ombrage à l'Université des Philippines à Los Baños, en collaboration avec l'Université d'état de Caroline du Nord pour mettre au point des cultivars/des lignées qui tolèrent l'ombre.

Le criblage de 552 obtentions sous ombrage artificiel de 40 à 58% a mené à l'identification de certains matériels tolérant l'ombre. Ils servaient soit de géniteurs dans 57 croisements pour le développement de lignées tolérantes de l'ombre, soit d'obtentions dans une série d'essais de rendement sous cocotier.

Six cultivars/lignées (IPB Pn 82 80-5, IPB Pn 82 82-85, IPB Pn 82 71-26, IPB Pn 82 71-32, UPL Pn 2, et UPL Pn 8) ont été identifiés comme ayant un fort rendement dans différents endroits et durant différentes saisons. Ils sont actuellement en voie d'évaluation dans des essais en milieu réel à Davao, Province d'Aurora, Bicol, Quezon et Nord Cotabo.

IPN Pn 82 68-68 est une lignée tolérant l'ombre et qui promet beaucoup. Elle a produit un fort rendement dans des essais sur le terrain menés simultanément sous une structure d'ombrage artificiel (par exemple 4 niveaux d'ombre au moyen de tissu d'ombrage Saran) et dans des conditions naturelles (par exemple deux emplacements d'essai de cocotier) pendant la saison sèche de culture des années 1990/91.

1. Groundnut Breeder, University Researcher, and Research Assistant, Institute of Plant Breeding, University of the Philippines, at Los Baños, College, Laguna, Philippines.

Growth Habit in Groundnut: A Comparative Analysis of F_2 Progenies

N.B. Essomba[1] and T.A. Coffelt[2]

Growth habit is an important trait in groundnuts as it influences sowing density. For this trait groundnut germplasm is commonly classified into two main forms – erect and runner. A wide range of stable intermediates exists between the typical erect and typical runner forms. Although some authors use other designations, these intermediates are usually grouped subjectively under the two basic forms. Lack of a definitive method of classifying the intermediate forms may account for the diverse reports concerning the inheritance of this trait. IBPGR and ICRISAT suggest classifying groundnut plants using six progressive groupings based on the curvature of lateral branches and the height of the main stem. This study compares the traditional analysis (based on two groupings) with a new one adapted from the graded scale. It was conducted on F_2 progenies obtained from a diallel design excluding self-crosses. Three parents, comprising one *Arachis monticola* cultivar and two groundnut cultivars (Argentine and T2442), were used. All progenies were grown on the farm of Tidewater Agricultural Experiment Station (USA) during 1985 on a Kenansville loamy sand.

The traditional analysis was based on genetic ratio testing, whereas the new one was based on the interpretation of second, third, and fourth degree, and other statistics of progeny distributions. Results from the two analyses are contrasted and discussed with regard to the number of segregating genes, the relationships within and between these genes, and the interference of extra-nuclear factors. The two analyses have not shown any major contradiction on these issues though one may have more precisely addressed one aspect than the other. They have appeared to be complementary instead. They indicate that growth habits may indeed be quasi-quantitatively determined by a mixture of major and minor genes in groundnuts.

Port de croissance chez l'arachide: analyse comparative de progéniture F_2

Le port de croissance est un aspect important de l'arachide, car il influence la densité des semis. A ce point de vue les ressources génétiques d'arachide sont classées couramment en deux formes principales: érigé et rampant. Il existe une vaste gamme d'intermédiaire stables entre les formes typiques érigées et rampantes. Bien que certains auteurs emploient d'autres descriptions ces intermédiaires sont généralement groupés sous les deux formes de base. L'absence d'une méthode indiscutable de classement des formes intermédiaires peut expliquer la diversité des rapports relatifs à l'hérédité de cet aspect. Tant le CIRPG que l'ICRISAT suggèrent de placer les plants d'arachide dans six catégories progressives basées sur la curvature des embranchements latéraux et la hauteur de la tige principale. Cette étude compare l'analyse traditionnelle (basée sur deux groupements) avec une nouvelle adaptée d'après l'échelle graduée. Ceci a été fait sur les progénitures F_2 , obtenues d'après un dispositif dialélique excluant les croisements consanguins. Trois parents, comprenant un cultivar d'*Arachis monticula* et deux cultivars d'arachide (Argentine et T2442) ont servi. Toutes les progénitures ont été cultivées dans l'exploitation de la station expérimentale de Tidewater (Etats-Unis) en 1985 sur un sable limoneux de Kenansville.

L'analyse traditionnelle était basée sur les essais du ratio génétique, tandis que la nouvelle analyse est basée sur l'interprétation des deuxième, troisième et quatrième degrés et d'autres statistiques de répartition des

1. Research Officer, Institute of Agricultural Research, Nkolbisson Centre, P.O. Box 2067 Yaounde, Cameroon.
2. Research Geneticist, USDA-ARS, Groundnut Production, Diseases and Harvesting Research Unit, P.O. Box 7099, Suffolk, VA 2343, USA.

progénitures. Les résultats des deux analyses donnent un contraste et sont examinés en fonction du nombre de gènes ségrégants, du rapport intra et inter gènes et de l'ingérence extra nucléaire. Les deux analyses n'ont pas montré de contradictions sérieuses sur ces aspects, bien que l'une des deux ait pu porter plus particulièrement sur un aspect que l'autre. En fait, les résultats semblent complémentaires. Ils indiquent que les ports de croissance peuvent être quasi-quantitativement déterminés par un mélange de gènes majeurs et mineurs chez l'arachide.

Breeding Groundnuts Resistant to Aflatoxin Contamination at ICRISAT

H.D. Upadhyaya, V.K. Mehan, S.N. Nigam, D.H. Smith, and D. McDonald[1]

Breeding high-yielding groundnut genotypes resistant to infection and colonization by *Aspergillus flavus* and/or aflatoxin production is one of the major research objectives at ICRISAT. We have used several sources of resistance to seed infection/colonization by *A. flavus* and aflatoxin production in our breeding program. These resistant genotypes are crossed with high-yielding susceptible cultivars in an effort to combine different sources of resistance.

We have developed several high-yielding lines with levels of seed infection/colonization lower than in the resistant sources under imposed drought stress conditions. Some of these are ICGVs 88145, 89065, 89092, 89112, and 89115. Three other lines, ICGVs 87094, 87107, and 87110, had lower than average seed contamination with *A. flavus* in multilocational testing in Niger.

Studies on allelic relationship in different sources of resistance and on inheritance of resistance to seed colonization and aflatoxin production are in progress.

Sélection d'arachides résistants à la contamination par l'aflatoxine à l'ICRISAT

L'un des principaux objectifs de recherche chez l'ICRISAT consiste à sélectionner des génotypes d'arachide à haut rendement qui résistent à l'infection et à la colonisation par *Aspergillus flavus* et/ou la production d'aflatoxine. Nous avons employé différentes sources de résistance à l'infection/colonisation des semences par *A. flavus* et la production d'aflatoxine dans notre programme de sélection. Ces génotypes résistants sont croisés avec des cultivars sensibles à haut rendement, en vue de combiner différentes résistances.

Nous avons développé plusieurs lignées à haut rendement avec des niveaux d'infection/colonisation de semence plus faibles que dans les sources de résistance sous des conditions de stress imposées par la sécheresse. Certaines de ces lignées étaient ICGV 88145, 89065, 89092, 89112, et 89115. Trois autres lignées, ICGV 87094, 87107, et 87110 présentaient une contamination de semences par *A. flavus* inférieure à la moyenne dans des essais multilocaux au Niger.

Des études sur les rapports alléliques de différentes sources de résistance et de l'hérédité de la résistance à la colonisation des semences et à la production d'aflatoxine sont en cours.

1. Plant Breeder, Plant Pathologist, Principal Plant Breeder, Principal Plant Pathologist, and Program Director (Legumes), International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh 502 324, India.

Development of Improved Cultivars with Multiple Resistance to Insect Pests and Bud Necrosis Virus and its Vector

S.L. Dwivedi, G.V. Ranga Rao, G.V.S. Nagabhushanam, J.A. Wightman, D.V. Ranga Rao, D.V.R. Reddy, H. Bueil, and S.N. Nigam[1]

Groundnut leaf miner (*Aproaerema modicella*), tobacco caterpillar (*Spodoptera litura*), aphids (*Aphis craccivora*), jassids (*Empoasca kerri*), thrips (*Thrips palmi*), and termites are the major insect pests that cause substantial damage to the groundnut crop. *Thrips palmi* is the vector of bud necrosis virus and *A. craccivora* is the vector of groundnut rosette virus in Africa. Multiple resistance to thrips, jassids, and termites (pod scarification) has been identified in ICGs 2271, 5040, 5043, 5044, and 5045. High levels of resistance to aphids have been found in ICG 5240 and ICG 5725. Tolerance to leaf miner was located in a foliar disease-resistant germplasm line, ICG 1697. These lines have been crossed with several high-yielding but susceptible genotypes. Moderate levels of resistance to jassids and thrips have been transferred into high-yielding varieties. These varieties have shown yield advantages ranging between 117 and 330% compared to resistant parents. A thrips and jassid-resistant variety, ICGV 86031, has also shown tolerance to leaf miner and *Spodoptera*. It is also resistant to bud necrosis virus. Resistance to leaf miner and *Spodoptera*, located in several wild species, is to be exploited to improve the level of resistance in the cultivated types. Groundnut cultivars with multiple resistance to insect pests are likely to be included as a component in Integrated Pest Management (IPM) studies. Transferring multiple resistance into early-maturing types is a priority in breeding programs. Genetic studies on aphid resistance is in progress.

Développement de cultivars améliorés à résistance multiple aux insectes ravageurs et au virus de la nécrose des jeunes pousses et à son vecteur

La mineuse des feuilles de l'arachide (*Aproaerema modicella*), la chenille du tabac (*Spodoptera litura*), les aphidés (*Aphis craccivora*), les jassidées (*Empoasca kerri*), les thrips (*Thrips palmi*), et les termites sont les principaux insectes ravageurs qui causent des dégâts importants à la culture arachidière. *Thrips palmi* est le vecteur du virus de la nécrose des pousses et *A. craccivora* est le vecteur du virus de la rosette de l'arachide en Afrique. Une résistance multiple aux thrips, aux jassidés et aux termites (scarification des gousses) a été identifiée chez ICGV 2271, 5040, 5043, 5044, et 5045. Des niveaux élevés de résistance aux aphidés ont été trouvés chez ICG 5240 et ICG 5725. La tolérance à la mineuse de feuilles a été localisée dans une lignée résistante à la maladie foliaire, ICG 1697. Ces lignées ont été croisées avec différents génotypes à haut rendement mais sensibles. Des niveaux modérés de résistance aux jassidés et aux thrips ont été transférés à des variétés à haut rendement. Ces variétés ont manifesté des avantages de rendement allant de 117 à 330% de rendement, en comparaison avec les parents résistants. Une variété résistante aux thrips et aux jassidés, ICG 86031, a également manifesté de la tolérance à la mineuse des feuilles et à la *Spodoptera*. Elle est aussi résistante à la nécrose des pousses. La résistance à la mineuse des feuilles et à la *Spodoptera*, qui se trouve dans plusieurs espèces spontanées va être exploitée pour améliorer le niveau de résistance chez les types cultivés. Les cultivars d'arachide à résistance multiple aux insectes ravageurs semblent pouvoir être inclus comme éléments des études sur la défense intégrée des cultures. Le transfert de résistance multiple dans des types à maturité précoce est une priorité des programmes de sélection. Des études génétiques sur la résistance aux aphidés sont en cours.

1. Plant Breeder, Entomologist, Research Associate, Principal Entomologist, Research Associate, Principal Plant Virologist, Research Scholar, and Principal Plant Breeder, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh 502 324, India.

Breeding Groundnuts for Rust and Late Leaf Spot Resistance at ICRISAT

L.J. Reddy[1], S.N. Nigam[1], P. Subrahmanyam[2], D. McDonald[1], D.H. Smith[1], and J.P. Moss[1]

Rust (*Puccinia arachidis*) and late leaf spot (*Phaeoisariopsis personata*) are widely distributed fungal diseases of groundnut that cause substantial losses in yield of pods and haulms. Using simple and effective screening methods, several rust and late leaf spot-resistant genotypes have been identified at ICRISAT Center within the cultivated species. Most of these belong to the valencia group and are either poor yielders or have other agronomically unacceptable characters. Some wild *Arachis* species are immune or highly resistant to the two diseases. Stable interspecific hybrid derivatives belonging to the virginia group have been developed at ICRISAT Center; they possess high levels of rust and late leaf spot resistances, but most of them are late maturing and have low shelling percentages. Through large-scale hybridization, using both groundnut germplasm and the resistant interspecific hybrid derivatives, we have developed several high-yielding, agronomically acceptable resistant varieties. Some of these rust and late leaf spot resistant varieties also have resistance to other stresses such as drought, jassids (*Empoasca kerri*), and leaf miner (*Aproaerema modicella*). Two of them, ICGV 87160 and ICGV 86590, have been released for general cultivation in India. Another variety (Tifrust 2), jointly developed by USDA–ARS (University of Georgia, Tifton, USA) and ICRISAT, has been released as Cardi Payne in Jamaica. From the resistant breeding populations supplied by ICRISAT, cooperators in India have developed and released two varieties, Girnar 1 and ALR 1. Future research will concentrate on identification, characterization, and utilization of new sources of resistance to develop cultivars with higher levels of resistance to rust and late leaf spot, and suitable for diverse farming situations.

Sélection d'arachide à l'ICRISAT pour la résistance à la rouille et aux taches foliaires tardives

La rouille (*Puccinia arachidis*) et la tache foliaire tardive (*Phaeoisariopsis personata*) sont réparties largement parmi les maladies fongiques de l'arachide qui causent des pertes importantes de rendement de gousses et de fanes. Au moyen de méthodes de criblage simples et efficaces, plusieurs génotypes résistants à la rouille et à la tache foliaire tardive ont été identifiés parmi les espèces cultivées au centre de l'ICRISAT. La plupart appartiennent au groupe valencia et ont soit un mauvais rendement, soit d'autres caractéristiques agronomiquement inacceptables. Certaines espèces d'*Arachis* sauvage sont immunes ou hautement résistantes aux deux maladies. Des dérivés hybrides intespécifiques stables appartenant au groupe virginia ont été développés au centre de l'ICRISAT. Ils possèdent un niveau élevé de résistance à la rouille et aux taches foliaires tardives, mais la plupart d'entre eux ont une maturité tardive et ont de mauvais pourcentages d'écossage. Par l'hybridation à grande échelle, au moyen des ressources génétiques d'arachide et des dérivés hybrides interspécifiques résistants, nous avons mis au point plusieurs variétés résistantes à haut rendement et agronomiquement acceptables. Certaines de ces variétés résistantes à la sécheresse et à la tache foliaire tardive ont également de la résistance à d'autres contraintes, comme la sécheresse et les jassidés (*Empora kerri*) et la mineuse des feuilles (*Appraerema*

1. Senior Plant Breeder, Principal Plant Breeder, Program Director (Legumes), Principal Plant Pathologist, and Principal Cell Biologist, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh 502 324, India
2. Principal Groundnut Pathologist, SADCC/ICRISAT Groundnut Project, P.O. Box 1096, Lilongwe, Malawi.

modicella). Deux d'entre elles, ICGV 87160 et ICGV 86590, ont été vulgarisées pour la culture générale en Inde. Une autre variété (Tifrust 2), développée conjointement par l'USDA-ARS (Université de Georgie, Tifton, E.U) et l'ICRISAT a été vulgarisée comme "Cardi Payne" à la Jamaïque. A partir des populations résistantes fournies par l'ICRISAT, des coopérateurs de l'Inde ont développé et vulgarisé deux variétés, "Girnar 1" et "ALR 1". Les recherches à venir se concentreront sur l'identification, la caractérisation et l'utilisation de nouvelles sources de résistance pour développer des cultivars à haut niveau de résistance à la rouille et à la tache foliaire tardive, et convenant à différentes conditions d'exploitation.

NRGS 6: A High-yielding Foliar-disease-tolerant Interspecific Derivative of Groundnut

P. Sen, T.G.K. Murthy, T. Radhakrishnan, M.P. Ghewande, and P.S. Reddy[1]

The wild *Arachis* species are of interest in groundnut breeding, primarily as a source of disease and pest resistance. They are also useful in broadening the genetic base of cultivated groundnut. The interspecific breeding program at the National Research Center for Groundnut (NRCG) started in 1985. It has generated several advanced derivatives of crosses of groundnut, with various species in the section *Arachis*. NRGS 6 is one such derivative obtained from the cross between cultivars M 13 and *A. villosa*. The early-generation segregating material of the cross was collected from IARI Regional Research Station, Hyderabad in 1985. Single plants with disease resistance were selected from the F_8 bulks of this cross. The F_8 plant to F_9 row progenies were again evaluated for disease resistance and yield characteristics. One of these selections, CS 11, had semispreading habit, dark green foliage, and showed resistance to rust (*Puccinia arachidis*) and tolerance to leaf spots. It also had high yield and matured in 120 days in the rainy season. The line was multiplied and later tested for disease resistance and yield in 3 consecutive years. It yielded 11–13% more than the national control, Kadiri 3.

The line was renamed NRGS 6 and entered for large-scale testing under the All India Coordinated Research Project on Oilseeds (AICORPO) in 1989. Results of the multilocational tests confirmed that NRGS 6 was high yielding and rust resistant. With supplementary irrigation, NRGS 6 yielded 3.71 t ha^{-1} pods in the rainy season. NRGS 6 has been advanced to the final stage of testing (AVT II) under the AICORPO for the 1991 rainy season. It has 50.1% oil and 25% protein in its seeds. It has many nodules and is tolerant to damage from jassids (*Empoasca kerri*).

NRGS 6: Dérivé d'arachide inter-spécifique à haut rendement et tolérant la maladie foliaire

Les espèces sauvages d'*Arachis* ont de l'intérêt pour la sélection arachidière, surtout comme source de résistance à la maladie et aux ennemis. Elles sont également utiles pour élargir la base génétique de l'arachide cultivée. Le programme de sélection inter-spécifique au centre national de recherches de l'arachide NRGS a commencé en 1985. Il a fourni plusieurs dérivés avancés de croisements d'arachides avec diverses espèces de la section *Arachis*. NRGS 6 est un de ces dérivés obtenus par le croisement entre cultivars M 13 et *A. villosa*. Le matériel ségrégant de génération précoce de cet hybride a été collecté à la station d'IARI à Hyderabad en 1985. Des plants uniques à résistance à la maladie ont été sélectionnés de bulks F_8 de cet hybride. Les progénitures dans la rangée F_8 à F_9 ont de nouveau été évaluées pour la résistance à la maladie et les caractéristiques de rendement. Une de ces sélections, CS 11, avait un port semi-buissonnant, des feuilles vert foncé et manifestait de la résistance à la rouille (*Puccinia arachidis*) et de la tolérance aux taches foliaires. Elle avait aussi un grand rendement et parvenait à maturité en 120 jours en saison des pluies. La lignée a été multipliée et ensuite essayée pour résistance à la maladie et pour le rendement pendant trois années consécutives. Elle a donné 11 à 13 % de plus que le témoin national Kadiri 3.

La lignée a été renommée NRGS 6 et inscrite pour test sur grande échelle dans le cadre du projet de recherche coordonnée des graines oléagineuses de toute l'Inde (AICORPO) en 1989. Les résultats des essais multi-locaux

1. Head (Genetics and Cytogenetoics), Scientists (2) (Genetics and Cytogenetics), Scientist (Plant Pathology), and Director, National Research Center for Groundnut (NRCG), Junagadh 362 015, Gujarat, India.

ont confirmé que NRGS 6 avait un grand rendement et résistait à la rouille. Avec irrigation supplémentaire, NRGS 6 donnait 3,71 t ha^{-1} de gousses pendant la saison des pluies. NRGS 6 a été promu à l'étape finale des essais (AVT II) dans le cadre de l'AICOPRPO pour la saison des pluies de 1991. Ses semences contiennent 50,1% d'huile et 25% de protéines. Elle a de nombreux nodules et elle tolère les dégâts causés par les jassidés (*Empoasca kerri*).

Recent Advances in the Development of Improved Groundnut Confectionery Cultivars

S.L. Dwivedi, G.V.S. Nagabhushanam, S.N. Nigam, and R. Jambunathan[1]

Groundnut seeds are rich in oil and protein. About one-third of world groundnut production is used in the form of edible products. Groundnut cultivars with large elongated seeds and tapering ends, pink/tan seed coat, ease in blanching, and low oil with a high oleic/linoleic (O/L) ratio are most preferred for edible purpose. There is a preference for 3-4 seeded valencia types for 'in-shell' boiled nut consumption in Southeast Asia. Several high-yielding cultivars with 100-seed mass between 70 and 150 g and with an O/L ratio of 1.6–2.5 have been developed.

Germplasm lines with boiling traits are being evaluated for yield potential. ICGV 86564 in Burundi and Nepal, ICGV 86584 in Malawi, ICGV 86552 in Sudan, and ICGV 86028 in Vietnam showed greater pod yield advantage ranging from 10 to 75% over control cultivars. Currently the Fourth International Confectionery Groundnut Varietal Trial (ICGVT) is available for cooperators. Genetic studies have revealed that pod/seed traits are predominantly controlled by additive genetic variance. Germplasm lines (ICG 10847, ICG 8325, ICG 6427, and ICG 3043) with better combining ability for grade characteristics have been identified for use in breeding. Transgressive segregants for yield and for larger pod/seed size were exploited. Several issues involved in confectionery breeding are also mentioned.

Récents progrès du développement de cultivars d'arachide améliorés pour la confiserie

Les graines d'arachide sont riches en huile et en protéines. Environ le tiers de la production mondiale d'arachide sert sous forme de produit comestible. Les cultivars d'arachide à grands grains allongés et extrémités effilées, revêtement de grains rose/brun, facilité de blanchissement et faible teneur en huile avec un fort ratio oléique/linoléique (O/L) sont largement préférés comme arachides de bouche. Il y a une préférence pour les types valencia tri- ou quadri-graines pour la consommation d'arachide bouillie "en coque" en Asie du sud-est. Plusieurs cultivars à haut rendement à masse de 100 grains entre 70 et 150 grammes et à O/L de 1,6–2,5 ont été développés.

Des lignées de ressources génétiques à aspect satisfaisant pour l'ébullition sont en voie d'évaluation quant à leur potentiel de rendement. ICGV 86564 au Burundi et au Népal, ICGV 86584 au Malawi, ICGV 86552 au Soudan, et ICGV 86028 au Vietnam ont manifesté des avantages de rendement en gousse supérieurs de 10 à 75% au témoin. Couramment, le quatrième essai variétal international d'arachide de bouche (ICGVT) est disponible pour les coopérateurs. Des études génétiques ont révélé que des aspects gousses-semences sont essentiellement contrôlés par la variance génétique additive. Des lignées (ICG 10847, ICG 8325, ICG 6427, et ICG 3043) à meilleure aptitude à la combinaison pour caractéristiques de grade ont été identifiées pour usage dans la sélection. Les ségrégants transgressifs pour le rendement et pour des dimensions gousse/grains supérieures ont été exploités. Plusieurs problèmes en jeu pour la confection de la confiserie sont également mentionnés.

1. Plant Breeder, Research Associate, Principal Plant Breeder, and Principal Biochemist, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh 502 324, India.

The Productivity of Some Groundnut Genotypes for Forage, Kernel, and Oil Yields in the Guinea and Sudan Savannah Ecologies of Ghana

K.O. Marfo[1]

The productivity of groundnuts in the dry Sudan and Guinea Savannah ecologies of Ghana has been based on kernel and oil yields. However, as a result of high population increase in these areas, resulting in high pressure on the limited available land for livestock and crop production, crop residue yields by groundnuts to be utilized as fodder is becoming increasingly important.

In this study, some groundnut genotypes belonging to early, medium, and late maturity groups were evaluated for their productivity traits, namely, kernel, haulm, and oil yields at three sites representing the Guinea and Sudan Savannah ecologies, and also to determine the feasibility of selecting for the combined traits in a single genotype. The results indicate that for the early (90-95 days) and late (over 110 days) maturity materials, it was possible to select genotypes that combine all three traits. In the Sudan Savannah ecological zone, early-maturing groundnut varieties are usually desirable due to their ability to escape terminal drought, a frequent occurrence in this area. Thus the ability to develop early varieties with both high kernel and haulm yields would be an asset in such an ecology.

Productivité de certains génotypes d'arachide pour l'affouragement, la production de grains et l'huile dans les écologies de savane guinéenne et soudanienne au Ghana

La productivité de l'arachide dans les écologies de savane sèche, soudanienne et guinéenne, au Ghana est basée sur les rendements en grain et en huile, Toutefois, en conséquence d'une augmentation de la population dans ces régions, provoquant une forte pression démographique sur la terre restreinte qui est disponible pour l'élevage et la production de culture, les rendements de résidus de culture d'arachide pouvant être utilisés comme produit d'affouragement deviennent de plus en plus importants.

Dans cette étude, certains types d'arachide appartenant à des groupes à maturité précoce, moyenne et tardive, ont été évalués pour leurs aspects de productivité à savoir le grain, la paille et les rendements en huile, à trois emplacements représentant les écologies de savanes guinéenne et soudanienne. et aussi pour déterminer la possibilité de sélection pour les aspects combinés en un seul génotype. Les résultats indiquent que pour les matériels à maturité précoce (90–95 jours) et tardive (plus de 110 jours) il était possible de sélectionner des génotypes qui combinent les trois aspects. Dans la zone écologique de savane soudanienne, des variétés d'arachide à maturité précoce sont généralement souhaitables, en raison de leur aptitude à esquiver la sécheresse terminale, qui se produit souvent dans cette région. Donc, l'aptitude à développer des variétés précoces, avec un rendement élevé à la fois en grain et en paille, devrait être un atout dans une telle écologie.

1. Head, Food Legumes Section, Crops Research Institute, P.O. Box 52, Nyankpala/Tamale, Ghana.

Crop Physiology and Nutrition

Reserve Mobilization and Starch Formation in the Cotyledons of Germinating Groundnut Seeds

J.B. Misra, P.C. Nautiyal, S. Chauhan, and P.V. Zala[1]

The cotyledons of groundnut contain oil (36-40%), protein (21-36%), starch (1-6%), and sucrose (2-6%) as food reserves. These food reserves are utilized for early heterotrophic growth of the seedling. The mobilization of these food reserves from the cotyledons during germination was studied by determining periodically the levels of these components in the cotyledons of germinating seeds. The seeds of the variety J 11 were soaked in paper towels and then allowed to germinate in the dark at 28–30°C. The cotyledons of the germinating seeds were sampled at 24 h intervals commencing at 0 h. At each sampling, 4 replicates of 30 seeds each were used. Standard chemical procedures were used for analysis of cotyledons.

The significant changes in sucrose content accompanied by rather insignificant changes in oil content during the initial phase of seed germination suggest that sucrose endogenously present in the cotyledons is translocated to the growing axis. The pattern of increase in the free amino acids suggests that the proteolysis begins soon after imbibition.

Mobilisation de la réserve et formation d'amidon dans les cotylédons de semences d'arachide en germination

Les cotylédons d'arachide contiennent de l'huile (36–40%), de la protéine (21–36%), de l'amidon (1–6%), et du saccharose (2–6%), comme réserve alimentaire. Ces réserves alimentaires sont utilisées pour la croissance hétérotrophique précoce de la plantule. La mobilisation de ces réserves alimentaires des cotylédons pendant la germination a été étudiée en déterminant périodiquement les niveaux de ces éléments dans les cotylédons de semences en germination. On a fait tremper les semences de la variété J 11 dans des serviettes de papier et ensuite on les a laissé germer dans l'obscurité à 28–30°C. Les cotylédons des semences en germination ont été échantillonnés à 24 heures d'intervalle en commençant à 0 heure. A chaque échantillonnage, 4 répétitions de 30 semences chacune étaient utilisées. Les procédures chimiques standards servaient à l'analyse des cotylédons.

Les changements significatifs de la teneur en saccharose, accompagnés de changements plutôt insignifiants de la teneur en huile pendant la phase initiale de la germination de semences laissent entendre que le saccharose présent endogènement dans les cotylédons est transféré à l'axe de croissance. La manière d'augmentation des acides aminés libres semble montrer que la protéolyse commence peu de temps après l'inhibition.

1. Head (Biochemistry Section), Plant Physiology Scientist, Senior Technical Assistant, and Technical Assistant, National Research Center for Groundnut (NRCG), Junagadh 362 015, Gujarat, India.

Hot Water Treatment for Groundnut Seed

Tran Van Lai[1], Nguyen Huu Quang[2], and Nguyen Hai Nam[3]

Low soil temperature and soil moisture at sowing time results in slower germination and reduces the germination rate of seed. Individual farmers keep their own seeds from the previous season, and seed viability is normally between 60 and 80%. To obtain desirable plant populations in the field, most farmers in northern and central Vietnam use sprouted seeds for sowing, by using a hot-water treatment. Pods are sun-dried (6–8 hours) before shelling and seeds are carefully selected by removing small and damaged seeds. Selected seeds are treated with hot water at about 55–60°C for 3–4 hours, shade-dried for 2–3 hours, and kept in a warm place either in gunny bags or bamboo baskets. Only sprouted seeds are selected and carefully spaced 7–10 cm apart in furrows opened on raised beds and then covered by hand or foot. Nonsprouted seed can be used as food or feed.

The hot-water treatment method leads to faster emergence under low soil temperature, ensures good germination rates and plant density, avoids seed damage by soil insects or seedling diseases, allows re-use of nonsprouted seeds, and reduces seed rate by 20–30%. The method is not practicable when soil is dry at sowing time. Sprouted seeds need careful handling and seeds cannot be treated with other chemicals.

Traitement des semences d'arachide à l'eau chaude

Lorsque le sol est à basse température et à faible teneur en humidité au moment des semis, cela ralentit la germination et réduit le taux de germination des semences. Les cultivateurs individuels conservent leur propre semence de la campagne précédente et la viabilité semencière est normalement entre 60 et 80%. Pour obtenir des populations de plantes sur le terrain, la plupart des cultivateurs du Vietnam nord et centre se servent de semences pré-germées pour les semis, en employant un traitement à l'eau chaude. Les gousses sont séchées au soleil (6–8 heures) avant l'écossage, et les grains sont sélectionnés avec soin en supprimant ceux qui sont petits et endommagés. Les semences sélectionnées sont traitées à l'eau chaude à environ 55–60° C pendant 3–4 heures, séchées à l'ombre pendant 2–3 heures et conservées dans un endroit chaud soit dans des sacs de jute, soit dans des paniers de bambou. Seules les semences germées sont sélectionnées et elles sont espacées avec soin à 7–10 cm d'intervalle dans des sillons ouverts sur des lits de semences surélevés et ensuite couvertes manuellement ou d'un coup de pied. Les semences non germées peuvent servir à l'alimentation ou à l'affouragement.

Le traitement à l'eau chaude mène à une levée plus rapide lorsque les températures du sol sont basses; il assure un bon taux de germination et une bonne densité des plants, en évitant les dégâts causés aux semences par les insectes édaphiques ou les maladies des plantules. Il permet de réutiliser les semences non germées et réduit le taux de semences de 20–30%. La méthode n'est pas praticable lorsque le sol est sec au moment des semis. Les semences germées doivent être maniées avec soin et les semences ne peuvent pas être traitées avec d'autres produits chimiques.

1. Director, Legume Research and Development Center, National Institute of Agricultural Sciences, Hanoi, Vietnam.
2. Director, Department of Agriculture, Nghe Tinh Province, Vietnam.
3. Research Scholar (Crop Physiology), International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh 502 324, India.

Seed Viability in Groundnut

P.C. Nautiyal, V. Ravindra, P.V. Zala, and Y.C. Joshi[1]

In India groundnut is grown in two seasons, the rainy and the postrainy seasons. Produce from the postrainy season is generally not used for seed because it loses its viability rapidly during storage. The mechanism for the loss of seed viability in postrainy season produce is not well understood. Certain factors known to enhance this process are: soil moisture content during pod development and harvest stages, method and temperature of drying of pods, and ambient relative humidity during postharvest storage.

Experiments were conducted at the National Research Center for Groundnut (NRCG), to study the genotypic differences in rate and extent of loss of seed viability and the effect of moisture stress during the pod development stage of the crop on seed viability. During postharvest storage, significant differences were observed in the extent of loss of seed viability among the 14 spanish groundnut varieties grown in the postrainy season. Moisture stress during the pod development phase in the postrainy season crop was found to adversely affect seed viability. Avoidance of moisture stress during pod development will probably enhance the seed quality of postrainy season produce.

The level of moisture in groundnut pods, which is about 40% at harvest, is reduced to 10% or less prior to storage. Experiments indicated that shade drying and DOR method (inverted-bundle drying) were superior to windrow drying.

A simple and economic storage method has been developed to prevent the exposure of pods to high humidity during monsoons, in which calcium chloride is used as a desiccant inside a polyethylene-lined gunny bag containing the groundnut pods. The postrainy season produce thus stored showed 80% germination even after 8 months of storage as compared to 10% when stored in the gunny bags without calcium chloride.

Viabilité des semences de l'arachide

En Inde, l'arachide est cultivée en deux campagnes, la saison des pluies et la saison post-pluviale. La production de la campagne post-pluviale n'est généralement pas utilisée comme semence, parce qu'elle perd rapidement sa viabilité pendant le stockage. Le mécanisme de viabilité de semences pendant la période post-pluviale n'est pas bien compris. On sait que certains facteurs intensifient ce processus: la teneur en humidité du sol pendant la formation de la gousse et aux étapes de la récolte, méthode de séchage des gousses et humidité ambiante relative pendant le stockage post récolte.

Des expériences ont été entreprises au National research centre for groundnut (NRCG), pour étudier les effets des différents génotypes sur le taux et l'importance de la perte de viabilité des semences et sur l'effet du stress hydrique pendant l'étape de développement des gousses sur la viabilité des semences. Pendant le stockage post récolte, des différences significatives ont été observées quant à l'ampleur de la perte de viabilité de semences parmi les 14 variétés du type spanish cultivés pendant la saison post-pluviale. Le stress hydrique pendant la phase de développement de la gousse en saison post-pluviale affecte négativement la viabilité de la semence. Eviter le stress hydrique pendant la formation de la gousse rehausse probablement la qualité de la semence dans la production de saison post-pluviale.

Le degré d'humidité dans les gousses d'arachide, qui est d'environ 40% à la récolte est réduit à 10% ou moins avant le stockage. Des expériences ont indiqué que le séchage à l'ombre et la méthode DOR (séchage en gerbes inverties) sont meilleurs que le séchage en andains.

1. Scientists, Technical Assistant, and Head, Plant Physiology, National Research Center for Groundnut (NRCG), Junagadh 362 015, Gujarat, India.

Une méthode simple et économique a été mise au point pour empêcher l'exposition des gousses à une forte humidité pendant les moussons; dans ce système le chlorure de calcium effectue la dessiccation à l'intérieur d'un sac de jute doublé de polyéthylène et contenant les gousses d'arachide. Les produits de la saison post-pluviale ainsi stockés germent à 80%, même après huit mois de stockage contre 10% lorsqu'ils sont stockés dans des sacs de jute sans chlorure de calcium.

Drought Research on Groundnut at ICRISAT

R.C. Nageswara Rao, L.J. Reddy, V.K. Mehan, S.N. Nigam, and D. McDonald[1]

Identification of drought-tolerant groundnut germplasm and breeding lines is one of the major research thrusts at ICRISAT Center. Drought tolerant genotypes were identified on the basis of total dry matter and pod yield productivity under water deficit conditions, simulated by line-source sprinkler technique during postrainy seasons. Detailed physiological studies indicated variability among genotypes for transpiration, water-use efficiency, and harvest index as under water-limited conditions.

Drought-tolerant genotypes identified were crossed with genotypes having wide adaptability. The progenies of these crosses were tested in national and international drought nurseries. Results from these trials showed superiority of drought-tolerant selections over the local checks in total dry matter productivity, but not necessarily in pod yields, indicating local specific effects on partitioning of dry matter to pods. Drought stress during the pod-filling stage showed enhanced invasion of pods and seeds by *Aspergillus flavus*, which causes aflatoxin contamination. Genotypes resistant to *A. flavus* invasion were identified under simulated terminal drought conditions. Future plans of research include: a) identification of genotypes with efficient root system, greater water-use efficiency, and improved harvest index, and b) the development of drought-tolerant genotypes with resistance to *A. flavus*.

Recherche sur la sécheresse de l'arachide à l'ICRISAT

L'identification des ressources génétiques et des lignées de sélection d'arachide qui tolèrent la sécheresse est l'un des efforts les plus importants au centre ICRISAT. Des génotypes tolérants de la sécheresse ont été identifiés sur la base de la matière sèche totale et de la productivité en rendement de gousses, dans des conditions de déficit hydrique, simulées par la technique de la pulvérisation par canalisation pendant les saisons post-pluviales. Des études physiologiques détaillées indiquent une variabilité entre les génotypes quant à la transpiration, à l'efficacité d'usage de l'eau et à l'indice de récolte dans des conditions de restriction de l'eau.

Les génotypes tolérants de la sécheresse identifiés ont été croisés avec des génotypes qui avaient une vaste adaptabilité. Les progénitures de ces hybrides ont été vérifiées dans des pépinières nationales et internationales d'étude de la sécheresse. Les résultats de ces essais montrent la supériorité des sélections tolérant la sécheresse par rapport aux essais locaux, en ce qui concerne la productivité globale de matière sèche, mais non pas nécessairement quant à la production de gousses, ce qui indique des effets spécifiques locaux sur la répartition de la matière sèche aux gousses. Le stress hydrique pendant l'étape de grenaison des gousses est suivi par une invasion plus forte des gousses et des semences par *Aspergillus flavus*, qui provoque la contamination par l'aflatoxine. Des génotypes résistants à l'invasion par *A. flavus* ont été identifiés sous des conditions de sécheresse terminale simulées. Les plans de recherche de l'avenir comprennent: a) l'identification de génotypes qui aient une rhizosphère suffisante, une meilleure efficacité de l'usage de l'eau et un indice de récolte amélioré, et b) le développement de génotypes tolérants de la sécheresse avec une résistance à *A. flavus*.

1. Crop Physiologist, Senior Plant Breeder, Plant Pathologist, Principal Plant Breeder, and Program Director (Legumes), International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh 502 324, India.

Variation in Improved Spanish Groundnut Germplasm for Drought Tolerance Under Field Conditions

N.R. Bhagat, K. Rajgopal, N.R. Ghetia, P.K. Bhalodia,and N.R. Meena[1]

An experiment was conducted to measure the extent of genotypic variation among spanish groundnut (subsp *fastigiata* Waldron var *vulgaris* Harz.) for drought stress.

A total of 29 accessions that exhibited drought tolerance under stress conditions during 1988 and 1989 were systematically screened in summer 1991 adopting a split-plot design. They included germplasm (17), indigenous variations of TMV 2 (3), improved strains (5), and cultivars (4). The normal (nine irrigations at 10–12 day intervals) and reduced (three irrigations at 27–30 day intervals) irrigation regimes served as main-plot treatments and varieties were randomized in subplots. The genotypes were evaluated for 15 traits and exhibited significant differences for 14 of these. Differences between normal and stress conditions were recorded in numbers of leaves, aerial pegs, immature pods, and pod weight, and percentage of pod-bearing plants. Genotype × irrigation interaction was evident in all traits except number of primary branches and 100-seed mass.

Yields of NRCG 100 (Ah 20 Ex. WAF), NRCG 2529 (26-5-11), NRCG 3562 (Culture 715), and NRCG 6660 (NC Ac 2391 Ex. TZA) were markedly reduced in stress conditions. NRCG 2310 (4-2-4-7 Ex. IND), NRCG 3787 (MGS 7 Ex. IND), and NRCG 3920 (TMV 9 Ex. IND) were superior under both normal and stress conditions. The best sources of tolerance are likely to be available in the indigenous landraces.

Variation des ressources génétiques améliorées de l'arachide du type spanish pour la tolérance à la sécheresse dans des conditions réelles

Une expérience a été entreprise pour mesurer l'ampleur de la variation génotypique chez l'arachide spanish (sous-espèce *fastigiata* Waldron var *vulgaris* Harz.) en ce qui concerne le stress hydrique.

Au total, 29 obtentions qui manifestaient de la tolérance à la sécheresse dans des conditions de stress en 1988 et 1989 ont été systématiquement criblées pendant l'été 1991 au moyen d'un dispositif split-plot. Il s'agissait des ressources génétiques (17), de variation indigènes de TMV 2 (3), de souches améliorées (5), et de cultivars (4). Les traitements de parcelles principales étaient des irrigations soit du type normal (neuf irrigations à 10–12 jours d'intervalle) soit réduit (trois irrigations à 27–30 jours d'intervalle) et les variétés étaient placées d'une manière aléatoire dans des sous-parcelles. Les génotypes ont été évalués d'après 15 caractéristiques et ont manifesté des différences significatives pour 14 d'entre elles. Les différences entre les conditions normales et de stress ont été signalées en ce qui concerne le nombre de feuilles, de gynophores aériennes, de gousses immatures et de poids de gousses et le pourcentage des plants qui portaient des gousses. L'interaction génotype × irrigation était évidente dans toutes les caractéristiques, sauf le nombre d'embranchements primaires et la masse de 100 semences.

Les rendements de NRCG 100 (Ah 20 ex. WAF), NRCG 2529 (26-5-11), NRCG 3562 (Culture 715), et NRCG 6660 (NC Ac 2391 Ex. TZA) étaient nettement réduits dans des conditions de stress. NRCG 2310 (4-2-4-7 Ex. IND), NRCG 3787 (MGS 7 Ex. IND) et NRCG 3920 (TMV 9 Ex. IND) étaient supérieures dans des conditions tant normales que de stress. Les meilleures sources de tolérance seront probablement fournies par les races locales indigènes.

---

1. Head, Genetic Resources, Economic Botanist, and Technical Assistants, National Research Center for Groundnut (NRCG), Junagadh 362 015, Gujarat, India.

Enhanced Cytokinin Levels Associated with Good Mid-season Drought Recovery in Groundnut Genotypes

V.R. Sashidhar[1], R.V. Manju[1], L. Sudarshan[1], T.G. Prasad[1], M. Udaya Kumar[1], and R.C. Nageswara Rao[2]

Four genotypes previously tested in the field at ICRISAT Center and the University of Agricultural Sciences for distinct differences in recovery from mid-season drought stresses were grown in large containers, and 50-day-old plants were drought stressed until the soil water potentials reached -1.0 MPa. Cytokinin (CK) levels were determined in the xylem exudate at the end of the stress period, and at various periods during the first 2 weeks of recovery using enzyme-linked immunosorbent assay (ELISA) technique involving polyclonal antibodies raised against t-zeatin riboside. During the first 72 hours only the CK levels showed a relationship with recovery growth in the selected genotypes, which was assessed based on the additional leaf area, and pegs produced at the end of 2 weeks of recovery. The possible role of cytokinins in drought recovery from mid-season stresses is discussed.

Meilleurs niveaux de cytokinine associés à une bonne reprise après la sécheresse en mi-saison dans les génotypes d'arachide

Quatre génotypes précédemment testés sur le terrain au centre ICRISAT et à l'Université des sciences agricoles quant aux différences distinctives de reprise après les stress hydriques de mi-saison ont été cultivés dans de grand bacs et des plants de 50 jours ont été soumis au stress hydrique jusqu'à ce que le potentiel d'eau de leur sol ait atteint moins de -1,0 MPa. Les niveaux de cytokinine (CK) ont été déterminés dans l'exsudat de xylème à la fin de la période de stress et à diverses périodes pendant les deux premières semaines de reprise, au moyen de titrage d'immunoabsorbance liés aux enzymes (ELISA) mettant en jeux les anticorps polyclonaux contre le ribosyde de t-zeatine. Pendant les 72 premières heures seulement, le niveau de cytokinine manifestait un rapport avec la croissance de reprise de génotypes sélectionnés, qui a été évaluée sur la base de la surface foliaire additionnelle et des pousses produites à la fin de deux semaines de reprise. Le rôle possible des cytokinines pour la reprise après stress hydrique de la mi-saison est examiné.

1. Associate Professor, Department of Crop Physiology, Postgraduate Student, Assistant Professor, Department of Biochemistry, and Associate Professor and Professor, Department of Crop Physiology, University of Agricultural Sciences, Bangalore 560 065, Karnataka, India.
2. Groundnut Physiologist, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh 502 324, India.

Relevance of Whole Plant Water Use Efficiency as a Drought Resistance Trait: Relationship Between Container and Field Assessment of Groundnut Genotypes Under Limited Water Inputs

T.G. Prasad[1], V.R. Sashidhar[1], K. Balachandra Hebbar[1], M. Udaya Kumar[1], R. Devendra[1], and R.C. Nageswara Rao[2]

Very few attempts have been made to compare whole-plant water use efficiency (WUE) among genotypes within a species in container and field studies, particularly under a water-limited condition. Such an attempt is imperative if WUE is to be considered as a useful drought-resistance trait. In this study, an attempt was made with 14 bunch genotypes of groundnut to resolve the important question of whether genotypes selected for high WUE in container studies with limited water-inputs would also produce higher biomass under similar situations in the field with a long-duration water stress. The results suggested that the range in WUE in the container studies with the modified 'known water input technique' conformed to previous data for a C_3 species. Most genotypes showed a significant increase in WUE with a limited water input. Four genotypes selected for either high or low WUE under nonlimiting and limiting water inputs were further tested for field WUE under a long duration water stress from 44 to 90 days after sowing. Except for one, all other genotypes showed similar rankings in the field experiment. These genotypes (high WUE under control and stress in container experiment) also showed a higher biomass when given limited water in the field. The implication and significance of these data are discussed with respect to the relevance of whole plant WUE as a drought-resistance trait.

Applicabilité de l'efficacité de l'usage d'eau du plant entier comme caractéristique de résistance à la sécheresse: rapport entre l'évaluation en bac et sur le terrain de génotypes d'arachide avec intrants hydriques limités

Très peu d'essais ont été effectués de comparer l'efficacité de l'usage d'eau du plant entier (WUE) parmi les génotypes au sein d'une espèce dans des études en bac et sur le terrain, particulièrement dans des conditions de restriction d'eau. Un tel effort est impératif si le WUE doit être considéré comme une caractéristique utile de la résistance à la sécheresse. Dans cette étude, un effort a été fait au moyen de 14 génotypes buissonnants d'arachide pour résoudre la question importante de savoir si les génotypes sélectionnés en raison de leur forte WUE dans des études en bac avec intrant d'eau limité produiraient aussi une biomasse supérieure dans des conditions analogues sur le terrain avec un stress d'eau de longue durée. Les résultats ont laissé entendre que la gamme de WUE dans les études en bacs avec la "technique d'intrant d'eau connu" modifiée étaient conformes aux données obtenues précédemment pour une espèce C_3. La plupart de génotypes manifestaient une augmentation significative de WUE avec un intrant d'eau limité. Quatre génotypes sélectionnés en raison de WUE soit élevé soit bas, avec des intrants d'eau non limités et limités ont été testés davantage quant à la WUE sur le terrain pendant une longue

1. Associate Professors, Postgraduate Student, Professor and Associate Professor, University of Agricultural Sciences, Bangalore 560 065, Karnataka, India.
2. Groundnut Physiologist, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh 502 324, India.

durée de stress hydrique de 44 à 90 jours après les semis. Sauf dans un cas, tous les autres génotypes manifestaient un classement analogue dans l'expérience. Ils ont montré une biomasse plus élevée lorsque la quantité d'eau était restreinte terrain. L'implication et la signification de ces données sont examinées en ce qui concerne le degré auquel la WUE du plant total peut être considéré comme une caractéristique de résistance à la sécheresse.

Genetic Variation in Water-use Efficiency in Groundnuts

G.C. Wright[1] and R.C. Nageswara Rao[2]

Improvement in water-use efficiency (WUE), the production of biomass per unit of water transpired, is one trait that potentially enables superior performance of groundnut cultivars under drought stress. Glasshouse experiments have demonstrated that significant cultivar variation in WUE exists in groundnut, and that WUE is negatively correlated with the ratio of carbon isotopes $^{13}C/^{12}C$ (Δ) in leaves. This finding suggested Δ could provide an extremely efficient selection procedure for WUE in large-scale breeding programs.

Experiments were conducted to determine whether cultivar differences in WUE observed under glasshouse conditions were occurring in plants grown in canopies in the field under well-watered and water-limited conditions. Significant variation in WUE among groundnut cultivars was measured under well-watered and water-limited conditions, using mini-lysimeters located within field canopies. The cultivar Tifton 8 had the highest WUE (3.71 g kg^{-1}) and cv Chico the lowest (1.81 g kg^{-1}). In general, variation in WUE among cultivars occurred due to differences in biomass rather than to differences in water use, suggesting that photosynthetic capacity rather than leaf/canopy stomatal conductance dominates the WUE response in groundnut cultivars. In addition, it was observed that WUE was highly correlated with specific leaf area (SLA, or leaf thickness) suggesting that high WUE plants may have more photosynthetic machinery per unit leaf area. The correlation between WUE and Δ was extremely high under well-watered ($r = 0.67$) and water-limited ($r = 0.92$) conditions, indicating Δ has significant potential for use as a selection criteria for WUE in groundnut breeding programs. The identification of a strong correlation between Δ and SLA suggests selection for leaf thickness may well be as effective as selection for Δ.

Variation génétique de l'efficacité de l'usage de l'eau par l'arachide

L'amélioration de l'efficience d'usage de l'eau (WUE), la production de biomasse par unité d'eau transpirée, est un aspect qui permet potentiellement une performance supérieure des cultivars d'arachide sous stress hydrique. Deux expériences en serre ont démontré qu'une variation significative des cultivars du point de vue WUE existe chez l'arachide et que WUE présente une corrélation négative avec le ratio d'isotope de carbone $^{13}C/^{12}C$ (Δ) dans les feuilles. Cette constatation suggère que (Δ) pourrait fournir une procédure de sélection extrêmement efficiente pour la WUE dans des programmes de sélection à grande échelle.

Des expériences ont été entreprises pour déterminer si la différence entre les cultivars pour WUE, observée dans des conditions de serre, se produisait dans des plants cultivés sous canopie dans le champ, dans des conditions bien arrosées et avec des restrictions d'eau. Une variation significative WUE parmi les cultivars d'arachide a été mesurée sous des conditions de bon arrosage et de restriction d'eau en se servant de mini lysimètres placés sous les canopies sur le terrain. Le cultivar Tifton 8 avait la WUE la plus élevée (3,71 g kg^{-1}) et le cv Chico la plus faible (1,81 g kg^{-1}). En général la variation de WUE parmi les cultivars résultait des différences de biomasse plutôt que des différence d'usage d'eau, suggérant que la capacité photosynthétique, plutôt que la conductance stomatale feuille/canopie domine la réponse WUE chez les cultivars d'arachide. En outre, on a remarqué que la WUE présente une corrélation très élevée avec la surface foliaire spécifique (SLA ou

1. Principal Agronomist, Queensland Department of Primary Industries, P.O. Box 23, Kingaroy, 4610, Australia.
2. Groundnut Physiologist, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh 502 324, India.

épaisseur des feuilles) suggérant que les plants qui ont la WUE la plus élevée peuvent avoir davantage de dispositif de photosynthèse par unité de surface foliaire. La corrélation entre WUE et Δ était extrêmement élevée dans des conditions de bon arrosage (r = 0.67) et de restriction d'eau (r = 0.92), ce qui indique que Δ a un potentiel significatif d'usage comme critère de sélection en ce qui concerne la WUE dans les programmes de sélection arachidière. L'identification d'une forte corrélation entre Δ et la SLA suggère que la sélection pour l'épaisseur des feuilles pourra être aussi efficace que la sélection pour Δ.

Diagnosis and Correction of Iron Chlorosis in Groundnut

M.V. Potdar and M.M. Anders[1]

Iron chlorosis has been reported as a major nutritional constraint to groundnut production in several semi-arid tropical (SAT) countries including India. However, studies on diagnosis of this problem, and potential yield losses due to iron chlorosis under realistic farm conditions are negligible. On-farm diagnostic trials were, therefore, established in calcareous soils with a history of iron chlorosis at four locations in Andhra Pradesh and Maharashtra, including ICRISAT Center, during the postrainy season of 1990/91. Two land forms [flat vs broadbed and furrow (BBF)], two genotypes (local vs improved), and three iron treatments (control, $FeSO_4$, Fe-EDTA) as foliar sprays were evaluated in strip-split plot design with four replications. Disappearance of iron chlorosis symptoms after foliar iron sprays was used as a diagnostic index. The incidence of iron chlorosis was quantified by a visual scoring technique. Data on growth and yield collected at the final harvest were subjected to an analysis of variance.

Results showed that severe iron chlorosis can develop as early as seedling stage, and that the intensity of chlorosis symptoms varies within and between sites. Iron chlorosis symptoms were observed at three of the four experimental sites. Sowing groundnut on BBF was effective at one site in reducing the incidence of iron chlorosis, and contributed significantly to pod yield and yield components. All the genotypes tested were found to be highly susceptible to iron chlorosis. Among foliar sprays, spraying with 0.5% $FeSO_4$ was the most effective in correcting iron chlorosis and improving groundnut productivity. These studies further indicated that iron chlorosis can cause yield reductions of 46% for pod and 22% for fodder.

Diagnostic et correction de la chlorose ferrique chez l'arachide

La chlorose ferrique a été signalée comme étant une grande contrainte nutritive de la production de l'arachide dans plusieurs pays tropicaux semi-arides, y compris l'Inde. Toutefois, des études sur le diagnostic de ce problème et les pertes potentielles de rendement dues à cette chlorose sous des conditions de production réalistes sont négligeables. Des essais de diagnostics en milieu réel ont donc été entrepris dans des sols calcaires qui ont une histoire de chlorose ferrique à quatre endroits dans les états d'Andhra Pradesh et Maharashtra, y compris le centre de l'ICRISAT pendant la saison post pluies de 1990-91. Deux formes de terrain [plats contre grande planche et sillons (BBF)], deux génotypes (local contre amélioré), et trois traitement ferriques (témoin, $FeSO_4$, Fe-EDTA), par pulvérisation foliaire, ont été évalués dans un dispositif strip-split à quatre répétitions. La disparition des symptômes de chlorose ferrique après pulvérisation foliaire de fer a servi de diagnostic. L'incidence de chlorose ferrique a été quantifiée par une technique de notation visuelle. Des données sur la croissance et le rendement collectées au moment de la récolte finale ont été soumises à une analyse de variance.

Les résultats ont montré qu'une grave chlorose ferrique peut se manifester dès l'étape des plantules, et que l'intensité des symptômes de chlorose varie intra et inter emplacements. Des symptômes de chlorose ferrique ont été remarqués à trois des quatre emplacements expérimentaux. Des semis d'arachide sur BBF ont été efficaces à un emplacement pour réduire l'incidence de chlorose ferrique et contribuer nettement au rendement en gousses et aux éléments du rendement. Tous les génotypes testés étaient hautement sensibles à la chlorose ferrique. Parmi les pulvérisations foliaires, la plus efficace pour corriger la chlorose ferrique et améliorer la productivité de l'arachide était 0,5% $FeSO_4$. Ces études ont indiqué par ailleurs que la chlorose ferrique peut causer des réductions de rendement de 46% de gousses et de 22% pour l'affouragement.

1. Agronomist and Principal Production Agronomist, Resource Management Program, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh 502 324, India.

Phosphorus Efficiency in Groundnuts

K.R. Krishna[1]

Crop yield loss due to nutritional constraints, particularly phosphorus, can be drastic. Soil P deficiency is widespread. Genetic selection and manipulation of groundnut for higher P efficiency should be a profitable strategy. Genetic variation exists for root characteristics such as root length and P uptake per root length, which directly or indirectly contributes to P uptake efficiency. Similarly, genetic variation in shoot and seed related characters that affect P efficiency have been identified. A groundnut genotype is more acceptable when it is efficient at different P levels. A good proportion (nearly 50%) of the 40 genotypes tested maintained higher P efficiency at two soil P levels.

Further research on selection and genetic manipulation for P efficiency in groundnuts is necessary.

Efficacité phosphorique chez l'arachide

La perte de rendement de récolte provoquée par des contraintes nutritives, particulièrement celle de phosphore, peut être très marquée. Une déficience de P dans le sol est répandue. La sélection génétique et la manipulation des arachides pour accroître l'efficacité de P doit être une stratégie rentable. La variation génétique existe en ce qui concerne les caractéristiques de racines, comme la longueur des racines et l'exportation de P par longueur racinaire, qui contribuent directement ou indirectement à l'efficacité d'exportation de P. De même, on a identifié une variation génétique de caractéristiques apparentée aux pousses et aux grains qui affectent l'efficacité de P. Un génotype d'arachide est plus acceptable quand il est efficient à plusieurs niveaux de P. Une bonne proportion (près de 50%) des 40 génotypes testés maintenaient une efficacité de P plus élevée à deux niveaux de P du sol.

De nouvelles recherches sur la sélection et la manipulation génétique pour l'efficacité de P chez l'arachide sont nécessaires.

1. Crop Physiologist, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh 502 324, India.

Calcium Uptake in Relation to Pod Development in Aerial Podding Genotype of Groundnut

M.V.R. Prasad and Y. Muralidharudu[1]

The aerial podding genotype of groundnut produces some aerial pods in addition to several underground pods. The calcium content of the aerial pod-kernels and shells of TAP 5 showed higher quantities of calcium as compared to that of its derivatives. Also, the pod yield of the aerial podding genotype showed an enhancement of the corresponding increase in the basally applied gypsum at the time of sowing, thereby indicating that this genotype allows calcium translocation from the root system to the developing gynophores and pod, which could be of considerable advantage in groundnut breeding.

Exportation de calcium en rapport avec le développement de la gousse dans le génotype d'arachide à formation aérienne des gousses

Le génotype d'arachide à gousse aérienne a produit certaines gousses aériennes, outre plusieurs gousses souterraines. La teneur calcique des gousses et grains aériens et des coques de TAP 5 a révélé des quantités plus fortes de calcium que celles de ses dérivés. Par ailleurs, le rendement en gousse, du génotype à gousses aériennes révélait un relèvement de l'augmentation correspondante du gypse appliqué basiquement au moment des semis, indiquant ainsi que ce génotype permet le transfert de calcium de la masse racinaire aux gynophores en développement et à la gousse, ce qui pourrait être d'un très grand intérêt pour la production arachidière.

1. Principal Scientist and Scientist, Directorate of Oilseeds Research, Rajendranagar, Hyderabad 500 030, Andhra Pradesh, India.

Interaction Between Yield Fluctuation of Groundnut and Climatic Changes in China

X. Naiquan and W. Zhongqiu[1]

Groundnut is one of the major oilseed crops in China. It is distributed from the mid-temperature zone to Hainan Island in the tropics and from the coastal areas in the east to Xinjiang Autonomous region in the west. Groundnut production has increased greatly since the liberation of China in 1949, and more particularly since 1979. For the last four decades, the area sown to groundnut in the country has increased 1.2 times with a 4.5-fold increase in total yield. Nevertheless, groundnut yield was unreliable over years and areas due to input factors of policy and material, and especially climatic factors.

China's vast area has complex terrains, diverse climatic conditions, and different farming systems that affect the characteristics and layout of groundnut sowing. The following are the major characteristics of the five main groundnut production areas.

The Huanghe River Valley. The area grown to groundnut makes up 48.2% of the total in the country with an yield of 57% of the total, giving it first place among the groundnut growing areas. The annual cumulative temperature above 10°C is 3500–4000° Cd, photoperiodism is 1300–1550 h, and precipitation is 450–900 mm. This is suitable for growing medium-maturing pearl-seeded bunch varieties.

The Yantze River Valley. The sown area to groundnut accounts for 16.3% of the total area, and 14% of the total yield. The annual cumulative temperature above 10°C is 3500–5000° Cd, photoperiodism is 1000–1400 h, and precipitation is 1000–1400 mm. This area is also suitable for growing medium-maturing pearl-seeded bunch varieties.

The Coastal areas of Southeast China. The areas sown to groundnut accounts for 30.2% of the total area and 22.9% of the total yield. The annual cumulative temperature above 10°C is 6000–9000° Cd, photoperiodism is 2500 h, and precipitation is 1200–1800 mm. This area is suitable for growing pearl-seeded varieties.

Northeast area. The area sown to groundnut occupies 4% of the total and the yield makes up to 3.3% of the total. The annual cumulative temperature above 10°C is 2300–3300° Cd, photoperiodism is 900–1450 h, and precipitation is 400–600 mm.

Yungui Plateau area. Area sown to groundnut accounts for 2.8% of the total and the yield amounts to 1.7% of the total. The annual cumulative temperature above 10°C is 3000–3250° Cd, photoperiodism is 1100–2200 h, and precipitation is 500–1400 mm.

In future, efforts must be made to promote groundnut production in the country through extension and application of the experiences from commodity production bases and various high yield models in the main groundnut production areas.

Interaction entre la fluctuation du rendement de l'arachide et les changements climatiques de Chine

L'arachide est l'une des principales cultures oléagineuses de Chine. Elle est répandue de la zone à température modérée jusqu'à l'île de Hainan sous les tropiques et des plaines côtières de l'est jusqu'à la région autonome de

1. Deputy Director, Scientific Management Department and Project Officer, Foreign Affairs Division, Chinese Academy of Agricultural Sciences (CAAS), Beijing, People's Republic of China.

Xinjiang dans l'ouest. La production d'arachide a largement augmenté depuis la libération de la Chine en 1949 et plus particulièrement depuis 1979. Pendant 4 décennies, la superficie plantée d'arachide a augmenté 1,2 fois, tandis que le rendement total a augmenté 4,5 fois. Néanmoins le rendement d'arachide a varié pendant les années et à travers les régions en raison d'intrants relevant de la politique et du matériel et spécialement des facteurs climatiques.

L'immense territoire de la Chine a des terrains complexes, des conditions climatiques variées et des systèmes d'exploitations agricoles différents, ce qui affecte les caractéristiques et les répartitions des semis d'arachide. *Voici les principales caractéristiques des 5 principales zones arachidières:*

La vallée du fleuve Huanghe. La superficie consacrée à la production arachidière représente 48,2% du total du pays, avec un rendement de 57% du total, ce qui en fait la première des zones productrices d'arachide. La température cumulative annuelle supérieure à 10°C est de 3500–4000° Cd; la luminosité est de 1300–1550 heures et la précipitation de 450–900 mm. Cela convient aux variétés buissonnantes à grain perlé à maturation moyenne.

La vallée du fleuve Yangtze. La zone cultivée d'arachide représente 16,3% du total et 14% du rendement total. La température cumulative annuelle supérieure à 10°C est de 3550–3000° Cd; la photopériode de 1000–1400 heures,et la précipitation de 1000–1400 mm. Cette région se prête aussi à la culture de variétés buissonnantes à grain perlé à maturation moyenne.

Les zones côtières de Chine du sud-est. Les terrains cultivés d'arachide représentent 30,2% du total de la superficie et 22,9% du rendement total. La température cumulative annuelle supérieure à 10°C est de 6000–9000° Cd, la photopériode de 2500 heures et la précipitation de 1200–1800 mm. Cette zone convient à la culture de variétés à grain perlé.

Zone Nord-est. La région cultivée d'arachide comprend 4% du total et le rendement représente 3,3% du total . La température cumulative annuelle supérieure à 10°C est de 2300–3300° Cd, la photopériode est de 900–1450 heures et la précipitation de 400–600 mm.

Zone du plateau Yungui. La superficie plantée d'arachide représente 2,8% du total et le rendement 1,7% du total. La température cumulative annuelle supérieure à 10°C est de 3000–3200°Cd, la photopériode de 1100–2200 heures, et la précipitation est de 500–1400 mm.

A l'avenir, il faudra faire des efforts pour promouvoir la production de l'arachide dans le pays par la vulgarisation et l'application d'expériences à partir des bases de la production et de modèles à hauts rendements dans les principales zones de production arachidière.

Screening of Groundnut Cultivars for Root Infection by Native Vesicular-arbuscular Mycorrhizal (VAM) Fungi in Relation to Crop Growth in Medium-black Calcareous Soil

P.K. Joshi[1]

Thirteen groundnut cultivars, including four virginia runner (GAUG 10, GAUG 11, Punjab 1, and M 13), three virginia bunch (TMV 10, Robut 33-1, and Kopergaon 1), five spanish bunch (JL 24, Girnar 1, J 11, AK 12-24, and EC 21136), and one valencia (Gangapuri) were screened for vesicular-arbuscular mycorrhizal (VAM) root infection in relation to different parameters of crop growth such as nodulation, nitrogen fixation, plant biomass, pod yield, and nutrient content (N, P, Fe, Mn, Zn, and Cu) during the rainy seasons of 1988 and 1989. The groundnut cultivars showed wide variability in root infection (30–92%) by native VAM fungi. Among the virginia runner cultivars, GAUG 10 performed better in terms of nodulation, nitrogen fixation, plant biomass, nutrient content, and pod yield. Within the virginia bunch group, TMV 10 proved to be better than both Robut 33-1 and Kopergaon-1 throughout crop growth in 1988, and only during the late stages of crop growth in 1989. In the spanish group, cultivar JL 24 proved to be the best in 1988 and AK 12-24 in 1989. The valencia cultivar, Gangapuri, performed as well as the best spanish cultivars in 1989. In general, virginia runner and virginia bunch cultivars proved to be superior to spanish and valencia types. The superior performance of these cultivars was mainly due to a greater root surface infected by native fungi.

Criblage des cultivars d'arachide pour l'infection racinaire par des champignons mycorrhizo-vesiculaires-arbusculaires (VAM) en rapport avec la croissance de la culture dans des sols calcaires mi-noirs

Treize cultivars d'arachide, y compris 4 rampants Virginia (GAUG 10, GAUG 11, Punjab 1, et M 13), 3 buissonnants Virginia (TMV 10, Robut 33-1, et Kopergaon 1), 5 buissonnants Spanish (JL 24, Girnar 1, J 11, AK 12-24, et EC 21136), et 1 Valencia (Gangapuri) ont été criblés pour déterminer l'infection racinaire myccorhizale vésiculaire arbusculaire (VAM) en ce qui concerne différents paramètres de croissance de la culture, notamment la nodulation, la fixation d'azote, la biomasse de plants, le rendement en gousses, et la teneur nutritive (N, P, Fe, Mn, Zn, et Cu) pendant les saisons des pluies de 1988 et 1989. Les cultivars d'arachide ont manifesté une grande variabilité de l'infection racinaire (30–92%) par des champignons VAM indigènes. Parmi les cultivars le Virginia rampant GAUG 10 a donné le meilleur résultat en ce qui concerne la nodulation, la fixation d'azote, la biomasse du plant, la teneur nutritive, et mieux que Robut 31 et Kopergaon-1 pendant toute la croissance de culture en 1988 et seulement pendant la dernière étape de la croissance de la culture en 1989. Dans le groupe Spanish, le cultivar JL 24 s'est avéré le meilleur en 1988 et AK 12-24 en 1989. Le cultivar Valencia Gangapuri, s'est comporté aussi bien que les meilleurs cultivars spanish en 1989. En général, les cultivars Virginia rampants et Virginia buissonnants se sont avérés supérieurs aux types Spanish et Valencia. Le comportement supérieur de ces cultivars résultait surtout du fait que les champignons indigènes affectaient une plus grande surface de sol.

1. Head (Microbiology), National Research Center for Groundnut (NRCG), Junagadh 362 015, Gujarat, India.

Responses of Groundnuts to Inoculation with Rhizobia in China

Zhang Xuejiang, Jiang Mulan, Jiang Rongwen, Yao Ruivin, and Li Jianbao[1]

Some strong compatible host plant × *Rhizobium* strain combinations have been selected, e.g., cultivar Xu Zhou 68-4 × strain 147-3. The compatible cultivars are inoculated with 10^6 cells of the appropriate rhizobial microsymbionts per seed in groundnut fields with less than a 10^4 indigenous population g $soil^{-1}$. The competitive recovery of inoculated strain(s) reached 26.7–33.3%. Areas of groundnuts inoculated with rhizobia were up to 84 000 hectares in 1986-1990. Yield increases were considerable from the trials.

Réponse d'arachides à l'inoculation au moyen de Rhizobia en Chine

Plusieurs combinaisons fortes et compatibles de plants hôtes × souches *Rhizobium* ont été sélectionnées, par exemple, le cultivar Xu Zhou 68-4 × souche 147-3. Les cultivars compatibles sont inoculés au moyen de 10^6 cellules de microsymbionts rhizobiens appropriés par semences dans des champs d'arachide où la population indigène est de 10^4 par g de sol. La reprise concurrentielle de souches inoculées a atteint 26.7–33,3%. Les zones de culture arachidière inoculées au moyen de Rhizobia allaient jusqu'à 84,000 hectares en 1986–1990. Les augmentations de rendement étaient considérables d'après ces essais.

1. Associate Professor, Assistant Professors (2), and Research Assistants (2), Oil Crops Research Institute, Chinese Academy of Agricultural Sciences, Wuhan, Hubei Province, People's Republic of China.

Diseases and Insect Pests

Groundnut Disease Problems in Vietnam

L.M. Thi[1], N.X. Hong[2], V.K. Mehan[3], and N.T. Ly[1]

Diseases are one of the major constraints to groundnut production in Vietnam. Organized research on groundnut diseases was initiated in 1985, and systematic surveys were conducted during 1989–1991 to assess the incidence and severity of diseases in various groundnut-growing areas of North and South Vietnam.

Rust (*Puccinia arachidis*) and late leaf spot (*Phaeoisariopsis personata*) are major fungal foliar diseases in the whole of Vietnam. The overlapping groundnut cropping seasons in southern Vietnam favor continuous perpetuation of the rust and late leaf spot pathogens. Early leaf spot (*Cercospora arachidicola*) can cause significant damage in some parts of northern Vietnam when early season rains are frequent. Bacterial wilt (*Pseudomonas solanacearum*) is becoming increasingly important in Nghe Tinh Province in northern Vietnam. Collar rot (*Aspergillus niger*) causes substantial seedling/plant mortality in some areas of Nghe Tinh Province. Pod rots are also major yield reducers in northern Vietnam. *Pythium* spp, *Fusarium* spp, and *Sclerotium rolfsii* appear to be involved in pod rots. Damping-off and seedling disease are economically important in southern Vietnam but their causal agents have not yet been identified. Several other fungal diseases occur only at low incidence. Virus diseases are not important. Research emphasis is on host-plant resistance to major diseases. Several ICRISAT germplasm/breeding lines have been found resistant to rust and late leaf spot in Vietnam. Integrated disease management strategies need to be considered for control of soilborne diseases. Research on etiology of pod rots and damping-off/seedling disease is in progress.

Problèmes pathologiques de l'arachide au Vietnam

Les maladies sont l'une des plus graves contraintes subies par la production arachidière au Vietnam. Des recherches organisées sur les maladies de l'arachide ont été entreprises en 1985 et des relevés systématiques ont été effectués en 1989-91 pour déterminer l'incidence et la gravité des maladies dans différentes zones de production arachidière du nord et du sud Vietnam.

La rouille (*Puccinia arachidis*) et la tache foliaire tardive (*Phaeoisariopsis personata*) sont les principales maladies foliaires fongiques de l'ensemble du Vietnam. Le chevauchement des saisons de culture d'arachide dans le sud Vietnam favorise une perpétuation continue des pathogènes de la rouille et de la tache foliaire tardive. La tache foliaire précoce (*Cercospora arachidicola*) peut provoquer des dégâts significatifs dans certaines parties du nord Vietnam, où fréquemment la saison des pluies commence tôt. Le flétrissement bactérien (*Pseudomonas solanacearum*) devient de plus en plus grave dans la province de Nghe Tinh, au nord Vietnam. La pourriture du collet (*Aspergillus niger*) cause une mortalité importante des plantules ou des plants de certaines parties de la province de Nghe Tinh. La pourriture des gousses est également une cause principale de perte de production dans le nord du Vietnam. *Phythium* spp, *Fusarium* spp, et *Sclerotium rolfsii* semblent jouer un rôle dans les pourritures de gousses. La fonte et les maladies des plantules sont économiquement mauvaises dans le sud du Vietnam, mais leurs agents causaux n'ont pas encore été identifiés. Plusieurs autres maladies fongiques ne se produisent qu'à un degré modéré. Les viroses ne sont pas très graves. La recherche se concentre sur la résistance du plant hôte aux principales maladies. Plusieurs lignées des ressources génétiques et sélections de l'ICRISAT ont manifesté de la résistance à la rouille et aux taches foliaires tardives au Vietnam. Des stratégies de gestion intégrée des maladies doivent être examinées pour lutter contre les maladies propagées par le sol. Des recherches sont entreprises sur l'étiologie des pourritures de la gousse et de la fonte et des maladies de la plantule.

---

1. Pathologists, Plant Protection Institute, Hanoi, Vietnam.
2. Pathologist, National Institute of Agricultural Sciences, Hanoi, Vietnam.
3. Plant Pathologist, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh 502 324, India.

Effect of Neem Products on the Control of Foliar Diseases of Groundnut

K.M. Usman, P. Durairaj, K. Karunanithi, and S. Thangavelu[1]

Field experiments were conducted at the Regional Research Station, Vridhachalam during the rainy seasons 1989/90 and 1990/91 to compare the efficacy of neem products and fungicides in the control of late leaf spot (*Phaeoisariopsis personata*) (LLS) and rust (*Puccinia arachidis*) diseases of groundnut using the cultivar JL 24.

Three neem products, namely, neem oil (3%), neem kernel extract (3%), and neem cake extract (5%) and the fungicides chlorothalonil (0.1%) and carbendazim (0.1%) + mancozeb (0.2%) were tested. Two sprayings were given: the first immediately after the appearance of the disease; and the second one a fortnight later. The incidence of late leaf spot and rust at 90 DAS and dry pod yield at harvest were recorded.

Pooled analysis of the data for the 2 years indicated that foliar application of chlorothalonil (0.1%) effectively controlled LLS (37.3%) and rust (38.94%) as compared to that of the unsprayed control for LLS (61.72%) and rust (61.85%). However, foliar application of neem kernel extract (3%) recorded the highest cost/benefit ratio in addition to reducing the foliar-disease incidence significantly.

Effets des produits du margousier sur la lutte contre les maladies foliaires de l'arachide

Des expériences ont été entreprises sur le terrain à la station de recherche régionale de Vridhachalam pendant les saisons des pluies 1989-90 et 1990-91 pour comparer l'efficacité des produits à base de margousier et des fongicides pour lutter contre la tache foliaire tardive (*Phaeoisariopsis personata*) LLS et la rouille (*Puccinia arachidis*) de l'arachide, au moyen du cultivar JL 24.

Trois produits du margousier, à savoir l'huile de margousier (3%), l'extrait d'amande de margousier (3%), et l'extrait de tourteau de margousier (5%) et des fongicides chlorothalonil (0,1%) et carbendazime (0,1%) + mancozed (0.2%) ont été essayés. Deux pulvérisations ont été faites: la première immédiatement après l'apparition de la maladie et la deuxième une quinzaine de jours plus tard. L'incidence de la tache foliaire tardive et de la rouille à 90 JAS et le rendement en gousses sèches à la récolte ont été notés.

Une analyse collective des données pendant les deux années indiquait que l'épandage foliaire de chlorothalonil (0,1%) maîtrisait effectivement la tache foliaire tardive (37,3%) et la rouille (38,94%) , en comparaison avec la lutte sans pulvérisation contre la tache foliaire (61,72%) et la rouille (61,85%). Toutefois l'épandage foliaire d'extrait d'amande de margousier (3%) donnait le meilleur rapport coût/avantage, outre que cela réduisait de manière significative l'incidence de la maladie foliaire.

1. Associate Professor, Professor, Assistant Professor (Plant Pathology), and Professor and Head, Regional Research Station, Tamil Nadu Agricultural University, Vridhachalam 606 001, Tamil Nadu, India.

Groundnut Foliar Diseases: Infection and Leaf Wetness

D.R. Butler and K.D.R. Wadia[1]

For infection to occur, rust (*Puccinia arachidis*) and leaf spot pathogens require the presence of liquid water on groundnut leaves. However, the effect of leaf wetness duration on infection has not been quantified.

Disease develops in the field under some weather conditions and not under others. Relationships between infection and weather variables such as leaf wetness and temperature are likely to provide a key to disease forecasting schemes. The purpose of these is to recommend use of expensive fungicides only when they would be most effective. Dew chambers are used to control temperature and leaf wetness.

Response curves for rust show that about 70% infection occurs with a 12 h wetness period at optimum temperatures (20–25°C). The period of leaf wetness after inoculation with a spore suspension must be continuous. If the continuity of wetness is broken, the amount of infection is reduced.

For late leaf spot (*Phaeoisariopsis personata*) disease, infection is greatest if leaf wetness is intermittent. After inoculation, lesions result only if the total wetness period exceeds 20 h (at 23°C). The number of lesions increases as the total wetness period increases beyond 80 h. With continuous leaf wetness for the same total period, the number of resulting lesions is much less.

These results allow us to relate leaf wetness to diseases in the field. They provide a rational framework for schemes to recommend the timing of fungicide applications. Preliminary schemes of this type are being field tested at ICRISAT Center.

Maladies foliaires de l'arachide: infection et humidité des feuilles

Pour que l'infection se produise, les pathogènes de rouille (*Puccinia arachidis*) et de tache foliaire exigent la présence d'eau liquide sur les feuilles d'arachide. Toutefois, on n'a pas quantifié l'effet de la durée de l'humidité de la feuille sur l'infection.

La maladie se développe sur le terrain dans certaines conditions climatiques mais pas dans d'autres. Des rapports entre l'infection et les variables du climat, par exemple, l'humidité de la feuille et la température, fourniront probablement une clef pour élaborer un plan de prévision de la maladie. Le but est de recommander l'usage d'insecticides couteux seulement lorsqu'ils seraient les plus efficaces. Des chambres de rosée servent à régler la température et l'humidité de la feuille.

Les courbes de réponse à la rouille montrent qu'environ 70% des infections se produit lorsque la période d'humidité est de 12 heures aux températures optimum (20°-25°C). La période d'humidité de la feuille après inoculation au moyen d'une suspension de spores doit être continue. Lorsque cette continuité d'humidité est interrompue, le degré d'infection est réduit.

En ce qui concerne la tache foliaire tardive (*Phaeoisariopsis personata*), l'infection est la plus forte lorsque l'humidité de la feuille est intermittente. Après l'inoculation des lésions ne se produisent que si la période totale d'humidité dépasse 20 heures (à 23°C). Le nombre de lésions augmente à mesure que la période totale d'humidité augmente au delà de 80 heures. Lorsque l'humidité de la feuille est continue pendant la meme période totale, le nombre de lésions qui en résulte est bien plus faible.

Ces résultats nous permettent d'établir un rapport entre l'humidité de la feuille et les maladies sur le terrain. Il fournissent un cadre rationnel de projets pour recommander le moment où les épandages de fongicides doivent être effectués. Des plans préliminaires de ce type subissent des essais sur le terrain au Centre ICRISAT.

1. Principal Microclimatologist and Research Associate, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh 502 324, India.

Research on Late Leaf Spot and Rust of Groundnut at ICRISAT

P. Subrahmanyam[1], D.H. Smith[2], V.K. Mehan[2], P.M. Reddy[2], L.J. Reddy[2], F. Waliyar[3], D. McDonald[2], A.K. Singh[2], and V. Ramanatha Rao[4]

Rust (*Puccinia arachidis*) and late leaf spot (*Phaeoisariopsis personata*) contribute to groundnut crop losses in many areas of the world. Research on exploitation of genetic resistance was initiated at ICRISAT Center in 1976. Effective field, greenhouse, and laboratory techniques have been developed for screening whole plants and/or detached leaves. Infector rows, infected potted plants, and sprinkler irrigations have been used to enhance disease development in field trials. Of over 12 000 germplasm accessions screened, lines resistant to either rust (124) or late leaf spot (54) have been identified. Twenty-nine lines are resistant to both diseases. Most of these genotypes have shown stable resistance in various locations. Approximately 80% of the rust and/or late leaf spot-resistant genotypes are valencia types (var *fastigiata*) that originated in Peru. These genotypes are low-yielding landraces with undesirable seed and pod traits. Several wild *Arachis* species were found resistant to these diseases. Components of resistance that may contribute to partial resistance are: long incubation period, small lesion/pustule size, low infection frequency, long latent period, and reduced sporulation. Future plans for research on late leaf spot and rust include studies of pathogen variability, identification of additional genotypes with resistance to late leaf spot and rust, and mechanisms of resistance in cultivated groundnuts and wild *Arachis* species.

Recherches sur la tache foliaire tardive et la rouille à l'ICRISAT

La rouille (*Puccinia arachidis*) et la tache tardive de la feuille (*Phaeoisariopsis personata*), contribuent dans bien des régions du monde à des pertes de récolte d'arachide. Des recherches sur l'exploitation de la résistance génétique ont été entreprises au centre ICRISAT en 1976. Des techniques efficaces sur le terrain, en serre et en laboratoire, ont été mises au point pour cribler des plants entiers et/ou des feuilles détachées. On s'est servi de rangées d'infecteurs, de plants infectés en pots et d'irrigation par arroseurs pour intensifier le développement de la maladie dans les essais sur le terrain. Sur plus de 12000 obtentions de ressources génétiques criblées on a identifié des lignées résistantes soit à la rouille (124), soit à la tache tardive des feuilles (54). Vingt-neuf lignées résistent aux deux maladies. La plupart de ces génotypes ont manifesté une résistance stable en divers lieux. Environ 80% des génotypes résistants soit à la rouille, soit à la tache tardive des feuilles, soit aux deux sont des types valencia (var *fastigiata*), dont l'origine était le Pérou. Ces génotypes étaient des races locales à faible rendement, qui ont des aspects indésirables des semences et des gousses. On a constaté que plusieurs espèces sauvages d'*Arachis* résistaient à ces maladies. Les éléments de résistance qui peuvent contribuer à une résistance partielle sont: une période d'incubation prolongée, petite dimension des lésions/pustules, faible fréquence d'infection, période de latence prolongée, et sporulation réduite. Les plans d'avenir pour la recherche sur la tache foliaire tardive et la rouille comprennent des études de variabilité des pathogènes, d'identification de génotypes additionnels, avec de la résistance à la tache foliaire tardive et à la rouille et des mécanismes de résistance dans les arachides cultivées et les espèces d'*Arachis* sauvage.

1. Principal Groundnut Pathologist, SADCC/ICRISAT Groundnut Project, P.O. Box 1096, Lilongwe, Malawi.
2. Principal Pathologist, Plant Pathologist, Research Associate, Senior Plant Breeder, Program Director (Legumes), and Germplasm Botanist, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh 502 324, India.
3. Principal Pathologist, ICRISAT Sahelian Center (ISC), Sadoré, Niger.
4. Genetic Diversity Officer, International Board for Plant Genetic Resources (IBPGR), via delle Sette Chiese 142, 00145 Rome, Italy.

An Integrated Approach to the Management of Foliar Diseases of Groundnut

M.P. Ghewande, S. Desai, Prem Narayan, and A.P. Ingle[1]

Cultivated groundnut is susceptible to several diseases that reduce realizable yields considerably. Early leaf spot (*Cercospora arachidicola*) (ELS), late leaf spot (*Phaeoisariopsis personata*) (LLS), and rust (*Puccinia arachidis*) are the major foliar diseases. Though attempts are made to control these diseases by different means, no serious efforts are made in India to integrate them to give cost-effective and efficient management. Hence, at the National Research Center for Groundnut, an effort was made to identify suitable components of disease control and then integrate them. The components included host-plant resistance, chemical, cultural, and biological control methods, and plant extract spray. Field experiments were laid out during the rainy seasons of 1988, 1989, and 1990 in a factorial experiment with three replications. Fifteen treatments involving various disease control measures, in sole crop and groundnut-red gram (T 21) intercrop, were applied to the groundnut cultivars (Girnar 1 and JL 24). Most effective control of early and late leaf spot control was achieved where groundnut was intercropped and was sprayed twice (55 and 70 DAS) with fungicide or received one spray each of neem leaf extract, fungicide, and cell-free filtrate of *Penicillium islandicum* inoculum.

These treatments, and the intercrops with neem leaf extract at 50 and 70 DAS, and with inoculum at 55 and 70 DAS gave the highest monetary returns. All intercrop treatments gave higher returns than sole-crop treatments. There is clearly scope for integration of suitable control measures even when disease-tolerant cultivars are used.

Une attitude intégrée à l'égard de la gestion des maladies foliaires de l'arachide

L'arachide cultivée est sensible à plusieurs maladies qui réduisent considérablement le rendement potentiel. La tache foliaire précoce (*Cercospora arachidicola*) (ELS), la tache foliaire tardive (*Phaeoisariopsis personata*) (LLS), et la rouille (*Puccinia arachidis*), sont les principales maladies foliaires. Bien que des efforts soient fait pour lutter contre ces maladies par différents moyens, aucun effort sérieux n'a été entrepris en Inde pour les intégrer afin d'assurer une gestion efficace et économique. Par conséquent, au Centre national de recherche de l'arachide, des efforts sont faits pour identifier des éléments propices pour lutter contre les maladies et ensuite les intégrer. Les éléments comprennent la résistance du plant hôte, des méthodes de luttes chimique, culturale et biologique et une pulvérisation d'extraits de plantes. Des expériences sur le terrain ont été entreprises pendant la saison des pluies de 1988,1989, et 1990 dans une expérience factorielle à trois répétitions. Quinze traitements comportant diverses méthodes de lutte contre les maladies, sur culture pure et sur culture associée/pois cajan (T 21), ont été appliquées à des cultivars d'arachide (Girnar 1 et JL 24). On a obtenu une maîtrise plus efficace des taches foliaires précoces et tardives lorsque l'arachide était en culture associée et pulvérisée deux fois (55 et 70 JAS), au moyen de fongicides ou lorsque l'arachide avait reçu une pulvérisation deux fois d'extrait de feuilles de margousier, de fongicide et d'un filtrant sans cellule d'un inoculum de *Penicillium islandicum*.

Ces traitements et la culture associée avec extrait de feuille de margousier à 50 et 70 JAS, et avec inoculum à 55 et 70 JAS ont donné les résultats financiers les meilleurs. Tous les traitements en culture associée ont donné des résultats supérieurs à ceux des cultures pures. Il y a nettement une possibilité d'intégrer une lutte qui convienne, même lorsqu'on se sert de cultivars tolérant la maladie.

1. Senior Scientist and Scientist (Plant Pathology), Senior Technical Assistant, and Technical Assistant, National Research Center for Groundnut (NRCG), Junagadh 362 015, Gujarat, India.

Components of Resistance to Late Leaf Spot of Groundnut in the Florida, USA, Breeding Program

F.M. Shokes and D.W. Gorbet[1]

Late leaf spot, caused by *Cercosporidium personatum*, is the major foliar disease of groundnut in Florida. Over the past 7 years, three intensive studies of components of resistance to this disease have been conducted. A comparison of Florunner to Southern Runner and UF 81206 showed that the latter two genotypes had rate-reducing resistance to late leaf spot due to reduced lesion size, lengthened latent period, and reduced sporulation. When latent periods were measured as time from inoculation until 50% of the lesions sporulated (LP_{50}), Southern Runner's latent period was 6 days longer than that of Florunner. UF 81206 never had greater than 10% of the lesions sporulating. The LP_{10} for UF 81206 was 40 days as compared to 22 days for Florunner and 24 days for Southern Runner. In another study of 116 genotypes, UF 81206 was found to have a latent period nearly twice as long as Florunner and only 25% of the sporulation of Florunner. Twenty-six of the genotypes tested had resistance indices from 25% to 125% greater than Southern Runner. Amount of sporulation was the strongest component measured in this study and accounted for 55% of the total variation of visible disease as rated by a plant appearance score. In the third study, comparing 14 genotypes, rate of disease progress and area under the disease progress curves were more highly correlated with the maximum percentage of sporulating lesions and latent period than with the degree of sporulation, lesion size, or percent necrotic area. Therefore, decreased sporulation and lengthened latent periods seem to be the strongest components of resistance to late leaf spot in the groundnut genotypes in the Florida breeding program.

Southern Runner, a cultivar released through the University of Florida Breeding Program, has rate-reducing resistance to late leaf spot as well as some resistance to rust (*Puccinia arachidis*) and web blotch (*Phoma arachidicola*). Since its release, Southern Runner has been found to have additional benefits: resistance to stem rot, caused by *Sclerotium rolfsii*, and resistance to tomato spotted wilt virus.

Eléments de résistance à la tache foliaire tardive de l'arachide dans le programme de sélection de Floride, E.U.

La tache foliaire tardive, causée par *Cercosporidium personatum*, est la principale maladie foliaire de l'arachide en Floride. Depuis 7 ans, trois études intensives des éléments de la résistance à cette maladie ont été effectuées. Une comparaison de Florunner et de Southern Runner et de UF 81206 a montré que ces deux derniers génotypes avaient une résistance qui réduisait l'intensité des taches foliaires tardives, en raison d'une réduction de la dimension des lésions, d'un prolongement de la période latente et d'une réduction de la sporulation. Lorsque des périodes latentes étaient mesurées selon la durée depuis l'inoculation, jusqu'à 50% des sporulations des lésions (LP_{50}) , la période latente de Southern Runner était plus longue de 6 jours que celle de Florunner. UF 81206 n'avait jamais plus de 10% de lésions sporulantes. Le nombre des lésions sporulées pour UF 81206 présentait une période latente presque deux fois plus longue que celle de Florunner et seulement 25% de la sporulation de Florunner. Vingt-six des génotypes essayés avaient des indices de résistance de 25 à 125% de plus que dans le cas de Southern Runner. La quantité de sporulation était l'élément le plus important mesuré dans cette étude et représentait 55% du total de la variation de la maladie visible, calculé d'après l'apparition sur le plant. Au cours de la troisième étude comparant 14 génotypes, les courbes d'avance de la maladie et de la superficie atteinte

1. Associate Professor and Professor, University of Florida, Institute of Food and Agricultural Sciences, North Florida Research and Education Center, Quincy, FL 32351, USA.

présentaient une corrélation plus forte avec le pourcentage maximum de lésions de sporulation et la période latente qu'avec le degré de sporulation, la dimension des lésions ou le pourcentage des zones nécrosées. Donc, la diminution de sporulation et la prolongation des périodes latentes, semblent être les éléments les plus forts de la résistance à la tache foliaire tardive dans les génotypes d'arachide du programme de sélection de Floride.

Southern Runner, cultivar vulgarisé par l'entremise du programme de sélection de l'Université de FLoride, a une résistance avec réduction du taux de la tache foliaire tardive et une certaine résistance à la rouille (*Puccinia arachidis*) et à "web blotch" (*Phoma arachidicola*). Depuis sa vulgarisation Southern Runner a manifesté d'autres avantages: résistance à la pourriture de la tige causée par *Sclerotium rolfsii*, et résistance au virus des taches bronzées de la tomate.

Management of Early Leaf Spot of Groundnut

P. Subrahmanyam, G.L. Hildebrand, and G. Schmidt[1]

Early leaf spot (*Cercospora arachidicola*) (ELS) is the most destructive disease of groundnut in the Southern African Development Coordination Conference (SADCC) region. The disease is widely distributed and occurs in epidemic proportions. Yield losses are generally substantial but vary considerably between locations and seasons. Although ELS can be controlled by certain fungicides, a large number of sprays are required for effective control and this practice may not be economically feasible to small-holder farmers. The SADCC/ICRISAT Groundnut Project located at Chitedze, Malawi, is currently investigating suitable low-input strategies for management of ELS. These strategies include utilization of genetic resistance, a minimal number of applications of suitable fungicide, and agronomic practices such as crop rotation, date of sowing, and cropping systems that lessen the risk of disease severity and minimize the impact on yield. Utilization of genetic resistance is a major component of the ELS management strategy. Some recently introduced South American germplasm lines have shown measurable levels of resistance to ELS and are being used in the breeding program. One or two strategically timed applications of fungicide were very effective in reducing yield losses. Crop rotation has markedly affected the onset and severity of ELS at Chitedze. In collaboration with the national programs of the region, we are developing a combination of these components into an effective ELS management package.

Gestion de la tache foliaire précoce de l'arachide

La tache foliaire précoce (*Cercospora arachidicola*) (ELS) est la maladie la plus dangereuse de l'arachide dans la région de la Conférence de coordination du développement en Afrique australe (SADCC). La maladie est largement répartie et revêt des proportions épidémiques. Les pertes de rendement sont généralement très fortes mais varient considérablement d'un endroit à l'autre et entre les saisons. Bien qu'ELS puisse être contrôlé par certains fongicides, un grand nombre de pulvérisations sont nécessaires pour assurer une maîtrise efficace et cette pratique n'est pas économiquement faisable pour les paysans cultivateurs. Le projet arachidier SADCC/ICRISAT, situé à Chitedze, Malawi, étudie à l'heure actuelle les stratégies à faibles intrants qui pourraient convenir à la gestion de l'ELS. Ces stratégies comprennent l'utilisation de résistance génétique, un nombre minime d'épandage de fongicide bien choisi et de pratiques agronomiques telles que la rotation des cultures, la date des semis et des systèmes d'exploitation qui réduisent le risque de gravité de la maladie et réduisent au minimum l'impact sur le rendement. L'utilisation de la résistance génétique est un élément essentiel de la stratégie de lutte contre ELS. Certaines lignées sud-américaines, récemment introduites ont manifesté un degré important de résistance à l'ELS et sont utilisées dans le programme de sélection. Un ou deux épandages de fongicide à des dates bien choisies ont donné de très bons résultats pour réduire les pertes. La rotation des cultures a affecté de manière marquée le début et la gravité de l'ELS à Chitedze. En collaboration avec les programmes nationaux de la région, nous mettons au point une combinaison de ces éléments pour en faire un ensemble de gestion d'ELS efficace.

1. Principal Groundnut Pathologist, Principal Groundnut Breeder, and Principal Groundnut Agronomist, SADCC/ICRISAT Groundnut Project, P.O. Box 1096, Lilongwe, Malawi.

Current Research on Viral Diseases at ICRISAT

D.V.R. Reddy[1]

Current research on groundnut viruses at ICRISAT Center is restricted to five viral diseases – peanut mottle (PMV), peanut clump (PCV), bud necrosis (BNV), peanut stripe (PStV), and cowpea mild mottle (CMMV) viruses. Various research activities on these viruses are outlined below under three headings.

Production of diagnostic aids. This includes production of polyclonal and monoclonal antibodies (as appropriate), and multiplication of seed of appropriate diagnostic hosts.

Screening for host-plant resistance and development of cultivars with resistance. This will be done by conventional methods, which include screening under high disease pressure, development of resistant cultivars, and multilocational testing in hotspots. Currently, cultivars with durable resistance to BNV are being developed. Genotypes with tolerance and nonseed transmission to PMV have been identified and are being evaluated at various locations. For nonconventional methods of introducing resistance, PCV was chosen. This work is being done in collaboration with the Scottish Crop Research Institute, Dundee, U.K. Viral genes have already been cloned and efforts are underway to identify the coat protein gene and to prepare suitable plasmid constructs.

International cooperation and technology transfer. We coordinate research on economically important groundnut viruses occurring in Asia (PStV, PMV, etc.) and in Africa (groundnut rosette, PCV, etc.). We facilitate access for national agricultural research systems (NARS) to advanced virology laboratories in developed countries to accomplish virus characterization and detection. We organize training courses at regular intervals for NARS scientists in the detection of viruses.

Recherche actuelle sur les viroses à l'ICRISAT

Les recherches actuelles sur les viroses au Centre ICRISAT sont restreintes à cinq maladies communiquées par des virus: la marbrure de l'arachide (PMV), le rabougrissement de l'arachide (PCV), la nécrose des bourgeons (BNV), les striures de l'arachide (PStV), et le "cowpea mottled virus" (CMMV). Diverses activités de recherche sur ces virus sont esquissées ci-dessous sous trois titres.

Production d'aide au diagnostic. Cela comprend la production d'anti-corps polyclonaux et monoclonaux (selon les besoins) et la multiplication d'hôtes diagnostiques appropriés.

Criblage pour résistance du plant hôte et développement de cultivars à résistance. Cela se fera par des méthodes conventionnelles, comportant le criblage sous forte pression de maladies, le développement de cultivars résistants et des essais multilocaux dans des endroits menacés. A l'heure actuelle, des cultivars à résistance durable au BNV sont en développement. Des génotypes à tolérance et à transmission non semencières au PMV ont été identifiés et sont en voie d'évaluation à divers endroits. Le PCV a été choisi pour des méthodes non conventionnelles d'introduction de la résistance. Ce travail se fait en collaboration avec l'Institut de recherche d'agriculture d'Ecosse, à Dundee, R.U. Des gènes de virus ont été clonés et des efforts sont entrepris pour identifier le gène de protéine de revêtement de semence et pour préparer des constructions plasmides appropriées.

Coopération internationale et transfert de technologie. Nous coordonnons les recherches sur des virus économiquement graves qui se produisent en Asie (PStV, PMV, etc.) et en Afrique (rosette de l'arachide , PCV, etc.). Nous facilitons l'accès pour les systèmes nationaux agricoles (NARS) à des laboratoires perfectionnés de virologie dans les pays développés, pour effectuer la caractérisation des virus et leur dépistage. Nous organisons des stages de formation à intervalles réguliers pour des scientifiques des NARS quant au dépistage de virus.

---

1. Principal Plant Virologist, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh 502 324, India.

Occurrence and Distribution of Groundnut Viruses in China

Xu Zeyong[1], Zhang Zongyi[1], D.V.R. Reddy[2], Chen Kurong[1], and Chen Jinxiang[1]

From surveys of groundnut virus diseases made in 15 groundnut-growing provinces and a municipality in China from 1983 to 1989, four groundnut virus diseases including groundnut mild mottle, yellow mosaic, common mosaic, and bud necrosis were found to be economically important and were caused by peanut stripe virus (PStV), cucumber mosaic virus (CMV), peanut stunt virus (PStV), and tomato spotted wilt virus (TSWV), respectively.

PStV occurred widely throughout all the groundnut growing regions in the country. However, it is mainly prevalent in the northern region, where PStV incidence was often over 50%. CMV was mainly prevalent in some locations in the northern region, causing severe damage to groundnut production. PStV was widely distributed in the northern region and spontaneously epidemic in the region. TSWV occurred in Guangdong and Guangxi provinces. High incidence of TSWV was observed in the suburbs of Guangchou city.

Some 1863 diseased samples were tested by enzyme-linked immunosorbent assay (ELISA). The results of ELISA tests were almost identical with those based on symptom diagnosis in the fields. However, mixed infection was often found in the yellow mosaic and common mosaic samples.

Apparition et répartition de l'arachide en Chine

D'après des relevés effectués dans 15 provinces arachidières et 1 municipalité de Chine de 1983–1989 sur les viroses de l'arachide, 4 viroses, y compris "le groundnut mild mottle", la mosaïque jaune, la mosaïque commune et la nécrose des bourgeons, ont été considérées comme économiquement graves et causées par le virus des striures de l'arachide, (PStV), le virus de la mosaïque du concombre (CMV), le virus du rabougrissement de l'arachide (PStV), et le virus des taches bronzées de la tomate (PSWV), respectivement.

PStV se produisait largement dans toutes les régions arachidières du pays. Toutefois, le virus est surtout présent dans la région nord, où l'incidence de PStV a souvent dépassé 50%. CMV était fréquent dans certains endroits de la région nord, causant des dégâts très graves à la production arachidière. PStV était largement réparti dans la région nord et spontanément épidémique dans cette région. TSWV se produisait dans les provinces de Guangdong et de Guangxi. Une forte incidence de TSWV était remarquée dans la banlieue de la ville de Guangchou.

Depuis 1963, des échantillons malades ont été testés par le titrage d'imunoabsorbants liés aux enzymes (ELISA). Les résultats des tests ELISA sont presque identiques à ceux basés sur le diagnostic des symptômes en champs. Toutefois, l'infection mixte était trouvée dans les échantillons de mosaïque jaune et de mosaïque commune.

---

1. Plant Pathologist, Assistant Professor, Research Scientist, and Research Assistant, Oil Crops Research Institute, Chinese Academy of Agricultural Sciences (CAAS), Wuhan, Hubei Province, People's Republic of China.

2. Principal Plant Virologist, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh 502 324, India.

Peanut Stripe Virus in Thailand

S. Wongkaew[1]

Six strains of peanut stripe virus (PStV) have been partially characterized in Thailand. They are serologically indistinguishable but give different symptoms on a set of differentiate hosts. Based on characteristic symptoms induced on Tainan 9 groundnut (subsp *fastigiata*), they are designated as mild, stripe, chlorotic ring-mottle, and necrotic strains. These strains caused mottling or mosaic symptoms on KC 84R cowpea (*Vigna unguiculata*). A variant of a chlorotic ring mottle strain that gives necrotic symptoms on KC 84R cowpea is designated chlorotic ring mottle CP-N. Apart from different symptomatology, the strains affect groundnut differently. Among them, the stripe and necrotic strains reduce pod yield drastically. Their seed transmission frequencies in Tainan 9 are also different.

Virus des striures de l'arachide en Thaïlande

Six souches du virus de la striure d'arachide (PStV) ne peuvent pas être distinguées l'une de l'autre sérologiquement, mais leurs symptômes sont différents sur un jeu d'hôtes différents.. Sur la base des symptômes caractéristiques induits sur Taïnan 9 (sous-espèce *fastigiata*) on les décrit comme étant des souches atténuées, à striures, à marbrure annulaire chlorotique et nécrosées. Ces souches ont causé des marbrures ou des symptômes de mosaïque sur le niébé KC 84R (*Vigna unguiculata*) . Une variante de la souche de marbrure annulaire chlorotique qui manifestait des symptômes nécrosés sur le niébé KC 84 R est intitulé marbrure annulaire chlorotique CP-N. En dehors d'une symptomatologie différente, les souches affectent la racine différemment. Parmi elles, les souches de striures et de nécrose réduisent les rendements en gousses énormément. Leurs fréquences de transmission de semences sur Tainan 9 sont également différentes.

1. Head, Department of Plant Pathology, Faculty of Agriculture, Khon Kaen University, Khon Kaen, Thailand.

Cooperative Research on Peanut Stripe Virus in China

Xu Zeyong[1], K.J. Middleton[2], D.V.R. Reddy[3], Zhang Zongyi[1], J.A. Wightman[3], Chen Kurong[1], and Chen Jinxiang[1]

Peanut stripe virus (PStV) is one of the most important viruses in China and Southeast Asian countries. Cooperative research between the Chinese Academy of Agricultural Sciences (CAAS) and the Australian Centre for International Agricultural Research (ACIAR) has been conducted in China in 1990 and 1991. Major research results are given below.

PStV early infection reduced groundnut yield by 20–40% in field conditions. Because of its wide epidemics, high incidence PStV is considered to be one of the most damaging groundnut viruses in China. A multilocational trial revealed that PStV could be epidemic throughout all the groundnut regions in China, even in the southern region where PStV is occasionally found if a virus source exists. Plastic film mulch was found to be effective for repelling aphid (*Aphis craccivora*), particularly in the early growing season, and was able to reduce PStV incidence in the 2-year trials. Groundnut line EC 36892 was highly resistant to aphids and reduced PStV incidence in a field trial. A groundnut line, F89-080, showed PStV low seed transmission (about 0.3%) in 3 years of testing.

Recherche coopérative sur la striure de l'arachide en Chine

Le virus de la striure de l'arachide(PStV) est l'un des virus les plus importants de Chine et des pays du sud-est de l'Asie. Des recherches coopératives entre l'Académie chinoise des sciences agricoles (CAAS) et le Centre australien de recherches agricoles internationales (ACIAR) ont été entreprises en Chine en 1990-91. Les principaux résultats de la recherche sont les suivants:

Une infection précoce à PStV a réduit le rendement des arachides de 20 à 40% sur le terrain. En raison des épidémies répandues, une forte incidence de PStV est considérée comme l'un des virus les plus dangereux de l'arachide en Chine. Un essai multilocaux a révélé que PStV pourrait être épidémique dans toutes les régions arachidières de Chine, même dans la région sud, où PStV est parfois trouvé, si une source de virus existe. Un paillis à film plastique a donné de bons résultats pour repousser les aphidés (*Aphis craccivora*), particulièrement pendant le début de la saison de croissance et a pu réduire l'incidence de PStV dans les essais qui ont duré deux ans. La lignée d'arachide EC 36892 était très résistante aux aphidés et réduisait les incidences de PStV dans les essais sur le terrain. Une lignée d'arachide, F89-080, manifestait un taux de transmission très faible dans les semences (0,3%) pendant les essais de trois ans.

1. Plant Pathologist, Assistant Professor, Research Scientist, and Research Assistant, Oil Crops Research Institute, Chinese Academy of Agricultural Sciences (CAAS), Wuhan, Hubei Province, People's Republic of China.

2. Regional Manager, Plant Pathology Branch, Queensland Department of Primary Industries, P.O. Box 23, Kingaroy, Queensland 4610, Australia.

3. Principal Plant Virologist and Principal Entomologist, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh 502 324, India.

ICRISAT Groundnut Lines Provide New Sources of Resistance to Bacterial Wilt in Indonesia

B. Soekarno and D. Sharma[1]

Bacterial wilt of groundnut caused by *Pseudomonas solanacearum* is an endemic disease in Indonesia. In the past, estimated crop losses amounted to 25% of the total groundnut crop and in some areas crop losses reached 90%. Release of a resistant variety, Schwartz 21 in 1925, reduced the losses and at present the incidence of bacterial wilt in farmers' fields is around 10%. However, most of the groundnut varieties in the country trace their origin to Schwartz 21 and consequently have a very narrow genetic base. Exotic introductions in the past have invariably been found susceptible.

Recently, introductions of late leaf spot (*Phaeoisariopsis personata*) and rust (*Puccinia arachidis*)-resistant lines from ICRISAT were evaluated for their reaction to bacterial wilt under natural and sick-plot conditions at Jambegede Experiment Station, Malang Agricultural Research Institute for Food Crops (MARIF) in East Java. A number of lines were identified with a survival of above 50% plants in contrast to 0-0.97% for chico and 1.58–3.2% for J 11, the susceptible check cultivars. The lines, ICGV 87165, ICGV 88252, ICGV 88271, and ICGV 88274 have been found to have multiple resistance to late leaf spot, rust, and bacterial wilt.

Des lignées d'arachide de l'ICRISAT fournissent de nouvelles sources de résistance au flétrissement bactérien en Indonésie

Le flétrissement bactérien de l'arachide causé par *Pseudomonas solanacearum* est une maladie endémique en Indonésie. L'an passé, on estimait que les pertes de récolte représentaient 25% du total de la récolte et dans certaines régions, les pertes atteignaient 90%. La vulgarisation d'une variété résistante, Schwartz 21 en 1925 a réduit les pertes et à présent l'incidence du flétrissement bactérien dans les champs paysans est d'environ 10%. Toutefois, la plupart des variétés d'arachide du pays remontent à Schwartz 21 et donc ont une base génétique très étroite. Les introductions exotiques dans le passé ont toujours été trouvées sensibles.

Récemment, des lignées de l'ICRISAT résistant à la tache foliaire tardive (*Phaeoisariopsis personata*) et à la rouille (*Puccinia arachidis*) ont été évaluées quant à leur réaction au flétrissement bactérien dans des conditions naturelles et en parcelles de pathologie à la station expérimentale de Jambegede, à l'Institut de recherches agricoles sur l'agriculture vivrière de Malang (MARIF) en Java oriental. Un certain nombre de lignées ont été identifiées qui ont une survie de plus de 50% des plants, contrairement aux 0-0,97% pour chico et 1,58–3,2% pour J 11, cultivars d'essai sensibles. Les lignées ICGV 87165, ICGV 88252, ICGV 88271 et ICGV 88274 ont révélé une résistance multiple à la tache foliaire tardive, à la rouille et au flétrissement bactérien.

1. Groundnut Breeder and Grain Legume Breeder (AARP), Malang Research Institute for Food Crops (MARIF), P.O. Box 66, Malang 65101, East Java, Indonesia.

Research on Groundnut Bacterial Wilt

Tan Yujun, Duan Laixiong, Liao Boshou, Li Wenrong, and Xu Zeyong[1]

Bacterial wilt caused by *Pseudomonas solanacearum* is an important groundnut disease in China. Scientists in the Oil Crops Research Institute of Chinese Academy of Agricultural Sciences have been conducting research on this disease since the 1960s. Some major results are briefly introduced below. Groundnut bacterial wilt is widely distributed throughout 17 groundnut growing provinces. However, it causes more serious damage to production in the central and southern regions in China. As many as 36 isolates collected from different geographical locations were divided into 7 pathotypes based on their pathogenicity to a set of groundnut cultivars with different levels of resistance. The wilt symptom in the field began at early growing stage and reached a spread peak at flowering and pegging stages when soil temperature at 5 cm depth was over 30°C. Rotation with rice (*Oryza sativa*) for 1 or 2 years could markedly reduce incidence of disease. Three years' rotation with rice could even eradicate bacterial wilt. Groundnut germplasm has been continually screened for resistance at the natural disease nursery in Hongan. Many new resistant sources have been found. New resistant cultivars such as Ehua 5 and Zhonghua 2 have been released and have played an important role in control of the disease since 1980. International cooperation with the Australian Centre for International Agricultural Research (ACIAR) and the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) on bacterial wilt is underway.

Recherche sur le flétrissement bactérien de l'arachide

Le flétrissement bactérien causé par *Pseudomonas solanacearum* est une maladie grave de l'arachide en Chine. Des scientifiques de l'Institut de recherches oléagineuses à l'Académie chinoise des sciences agricoles ont entrepris des recherches sur cette maladie depuis 1960. Certains grands résultats sont présentés brièvement ci-dessous. Le flétrissement bactérien de l'arachide est très répandu à travers 17 provinces qui pratiquent la culture arachidière. Toutefois, ils causent davantage de dégâts à la production dans les régions centre et sud de Chine. Jusqu'à 36 isolats collectés dans différents lieux géographiques ont été divisés en 7 pathotypes, basés sur leur pathogénicité pour un jeu de cultivars d'arachide qui avaient des niveaux de résistance différents. Le symptôme de flétrissement sur le terrain commençait à une étape précoce de la croissance et atteignait une crête aux étapes de la floraison et du piquetage, lorsque la température du sol à une profondeur de 5 cm étaient de plus de 30°C. La rotation avec le riz (*Oryza sativa*) pendant un ou deux ans pouvait réduire nettement l'incidence de la maladie. Une rotation de 3 ans avec le riz pouvait même éradiquer le flétrissement bactérien. Les ressources génétiques d'arachide ont été continuellement criblées pour la résistance à la pépinière des maladies naturelles de Hongan. Bien des sources nouvelles de résistance ont été trouvées. De nouveaux cultivars résistants, comme Ehua 5 et Zhonghua 2 ont joué un rôle important pour maîtriser la maladie depuis 1980. La coopération internationale sur la recherche sur le flétrissement bactérien a été entreprise avec le Centre australien de recherches agricoles internationales (ACIAR) et l'Institut international de recherche sur les cultures des zones tropicales semi-arides (ICRISAT).

1. Associate Professors, Assistant Professor, Associate Professor, and Plant Pathologist, Oil Crops Research Institute, Chinese Academy of Agricultural Sciences, Wuhan, Hubei Province, People's Republic of China.

How ICRISAT Ensures Export of Pest-free Groundnut Seeds

A.M. Ghanekar[1], K.S. Vara Prasad[2], and Ch. Ravinder Reddy[1]

The Plant Quarantine Unit (PQU) of ICRISAT is approved as an Export Certification Quarantine Laboratory by the Government of India (GOI). It works under the close supervision of the National Bureau of Plant Genetic Resources (NBPGR). Aspects pertaining to export of groundnut seeds are covered here.

Different entomological and pathological tests on groundnut seeds meant for export are carried out at ICRISAT Center. Such examined seed materials are submitted to officials of NBPGR for inspection and issuance of a Phytosanitary Certificate.

Although groundnut seeds are exported to several countries in the world, Asia and Africa are the major beneficiaries. Due to high plant quarantine standards of GOI and ICRISAT, not a single instance is cited for introduction of an exotic pest through seeds exported by ICRISAT. Since most of the groundnut seed is exported to developing countries that have minimal or nonexistent quarantine facilities, thorough quarantine inspection of seed material is essential.

Comment l'ICRISAT assure l'exportation de semences d'arachide exemptes d'insectes ravageurs

L'unité de quarantaine des plants (PQU) de l'ICRISAT est approuvée comme laboratoire de quarantaine pour exportation sous certification par le Gouvernement de l'Inde (GOI). Elle fonctionne sous la surveillance étroite du Bureau national des ressources génétiques des plantes (NBPGR). Les aspects relatifs à l'exportation des semences d'arachide sont couverts ici.

Différents tests entomologiques et pathologiques sur les semences d'arachide sont entrepris au centre ICRISAT. Les matériaux de semence ainsi examinés sont soumis à des représentants du NBPGR pour inspection et délivrance du certificat phytosanitaire.

Bien que les semences d'arachide soit exportées vers plusieurs pays du monde, les principaux bénéficiaires sont l'Asie et l'Afrique. En raison des normes de quarantaine des plantes très strictes du GOI et de l'ICRISAT, on ne connaît aucun cas d'introduction d'un ennemi exotique par les semences exportées par l'ICRISAT. L'inspection en quarantaine des semences est essentielle, car la majeure partie des pays en développement vers lesquels des semences d'arachide sont exportées n'ont que très peu ou pas de quarantaine.

1. Plant Pathologist and Head and Research Associate, Plant Quarantine Unit, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh 502 324, India.

2. Officer-in-Charge, Plant Quarantine Regional Station, National Bureau of Plant Genetic Resources, Rajendranagar, Hyderabad 500 030, India.

Groundnut Entomology Research at ICRISAT

J.A. Wightman, G.V. Ranga Rao, and D.V. Ranga Rao[1]

Three major objectives of groundnut entomologists at ICRISAT are to: a) generate and disseminate information that is not otherwise accessible to national agricultural research systems' scientists; b) carry out experiments at ICRISAT Center and in farmers' fields that may help to develop new approaches to the solution of pest management problems in the semi-arid tropics (SAT), and c) develop sets of practices that can be combined and modified to implement Integrated Pest Management (IPM) schemes in farmers' fields.

Research is thus directed towards collecting information about the applied ecology of the major groundnut pests and their natural enemies in the SAT and investigating and developing methods of managing these pests.

Background information has been collected about pest migration, damage–yield relationships, the effects of drought on insect performance, and pest population dynamics. More emphasis should be put on systematic pest surveys in the future.

Sources of resistance to the major above-ground pests have been located. The most potent sources of resistance are in the wild *Arachis* spp. Aphid (*Aphis craccivora*) resistance can now be screened by the biochemical analysis of phloem sap.

The future development of IPM programs in groundnut include the forecasting of pest outbreaks, growing varieties with resistance to key pests, and insecticide application regimes based on economic thresholds and the principles of insecticide resistance management.

Special emphasis research areas include virus vector ecology, and white grub management. The Legumes Entomology Unit attracts coworkers from cooperating laboratories to conduct research that is often of a more basic nature than that carried out by ICRISAT scientists.

Recherche entomologique de l'arachide à l'ICRISAT

Trois principaux objectifs des entomologistes de l'arachide de l'ICRISAT sont: a) assembler et diffuser les informations qui ne sont pas normalement disponibles dans les systèmes agricoles nationaux de recherche; b) entreprendre des expériences au Centre ICRISAT et dans des champs paysans pour aider à développer une nouvelle méthode afin de résoudre les problèmes de gestion des ennemis des récoltes dans les tropiques semi-arides; et c) mettre au point des jeux de pratique qui peuvent être combinés et modifiés pour appliquer les plans de gestion intégrée contre les ennemis dans les champs des cultivateurs.

La recherche vise donc à rassembler les informations sur l'écologie appliquée des principaux ennemis de l'arachide et de leurs ennemis naturels dans le sud-est asiatique et à enquêter et mettre au point des méthodes contre ces ennemis de l'arachide.

Les informations de base ont été rassemblées sur la migration des ennemis, les rapports dégâts-rendement, les effets de la sécheresse sur le comportement des insectes, et la dynamique des populations d'insectes. On devra insister davantage sur des enquêtes systématiques à cet égard à l'avenir.

Des sources de résistance aux principales maladies qui affectent l'arachide au-dessus du sol ont été dépistées. Les sources les plus puissantes de résistance qui se trouvent dans l'*Arachis* sauvage aux aphidés (*Aphis craccivora*) peuvent maintenant être criblées par l'analyse de la sève du phloème.

1. Principal Entomologist, Entomologist, and Research Associate, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh 502 324, India.

Le développement des stratégies de la lutte intégrée à l'avenir comporte la prévision des recrudescences d'ennemis, la culture de variétés qui présentent une résistance aux principaux ennemis et des régimes d'épandage d'insecticides basés sur un seuil économique, et les principes de gestion de la résistance aux insecticides.

Les zones principales de recherche comprennent l'écologie des vecteurs du virus et la lutte contre les vers blancs. L'unité attire des collègues de laboratoires coopérants pour entreprendre des recherches qui sont souvent d'une nature plus fondamentale que celles entreprises à l'ICRISAT.

Research on Applied Ecology of *Aproaerema modicella*, the Groundnut Leaf Miner at ICRISAT

J.A. Wightman, G.V. Ranga Rao, D.V. Ranga Rao, and K.N. Singh[1]

Research on the groundnut leaf miner (GLM) carried out at ICRISAT Center illustrates the approach being taken by legumes entomologists in developing 'tool boxes' that can be used to put together Integrated Pest Management (IPM) schemes. A long-term study of the population dynamics of GLM have indicated that the parasites and other natural enemies of this insect normally keep its density at levels that result in no yield reduction. The application of insecticides for the control of this or other pests can result in the disruption of the natural control process. Relationships between population density and yield loss have been established. Host-plant resistance in ICGV 86031 (tolerant) and ICGV 87160 (apparent antibiosis) have been located but have yet to be fully assessed by farmers.

Recherches sur l'écologie appliquée d'*Aproaerema modicella*, mineuse des feuilles de l'arachide, à l'ICRISAT

La recherche sur la mineuse des feuilles de l'arachide (GLM) entreprise au Centre ICRISAT illustre la méthode adoptée par les entomologistes des légumineuses pour développer des "trousses d'outils" qui peuvent servir à mettre sur pied des plans de lutte intégrée. Une étude à long terme des dynamiques de population de GLM a indiqué que les parasites et d'autres ennemis naturels de cet insecte maintiennent généralement sa densité à un niveau qui évite toute augmentation des pertes de rendement. L'épandage d'insecticide, la lutte contre cet ennemi et d'autres peuvent provoquer la disruption du processus naturel de maîtrise. Les rapports entre densité de population et perte de rendement ont été établis. La résistance du plan hôte ICGV 86031 (tolérant) et ICGV 87160 (antibiose apparente) a été localisée mais n'a pas encore été pleinement évaluée par les cultivateurs.

1. Principal Entomologist, Entomologist, and Research Associates, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh 502 324, India.

Effect of Nonconventional Methods for Managing Groundnut Leaf Miner

V.K.R. Sathiyanandam, R.K. Murali Baskaran, and S. Thangavelu[1]

Field experiments were conducted at the Regional Research Station, Vridhachalam, with the objectives of determining the influence of intercropping systems on population, efficacy of synthetic pyrethroids, and diflubenzuron, and estimating the economic threshold for managing the groundnut leaf miner, *Aproaerema modicella.*

Significantly fewer leaf miner larvae, a lower percentage of leaflet damage, and a higher percentage of parasitism by *Goniozus* sp were recorded in groundnut intercropped with pearl millet (*Pennisetum glaucum*) at 4:1 ratio with 4.7% increase net return over sole groundnut crop. Pearl millet plant sap prevented oviposition up to 74%.

The two pyrethroids deltamethrin (0.001%) and fenvalerate (0.01%) were superior in controlling leaf miner larvae and recording less leaf damage, each yielding pod of 1875 kg ha^{-1}. The threshold for taking plant protection measures was either two larvae $plant^{-1}$ or 9.8% leaflet damage.

Effets de méthodes non conventionnelles pour la lutte contre la mineuse des feuilles de l'arachide

Des expériences sur le terrain ont été entreprises au Centre régional de recherche à Vridhachalam, dans le but de déterminer l'influence des systèmes de cultures associées sur la population, l'efficacité des pyréthroides synthétiques et du diflubenzuron, et l'estimation du seuil économique de lutte contre la mineuse des feuilles, *Aproaerema modicella.*

Nettement moins de larves de mineuses des feuilles, un pourcentage plus faible de dégâts aux folioles et un pourcentage plus élevé de parasitisme par *Goniozus* sp ont été signalés dans l'arachide en culture associée avec le mil (*Pennisetum glaucum*) à un ratio 4:1, avec une augmentation nette de rapport de 4,7% par rapport à la culture pure d'arachide. La sève des plants de mil a empêché la ponte jusqu'à 74%

La déltamétrine (0,001%) et la fenvalérate (0,01%) étaient supérieures pour lutter contre les larves des folioles de l'arachide et on notait moins de dégâts aux feuilles, le rendement en gousse étant de 1875 kg ha^{-1}. Les seuils pour prendre des mesures de protection des plants sont ou bien deux larves par plant ou 9,8% de dégâts aux folioles.

1. Associate Professor and Assistant Professor (Agricultural Entomology), and Professor and Head, Regional Research Station, Vridhachalam 606 001, Tamil Nadu, India.

Review for Groundnut Pests and Diseases and IPM Implementation in Guangdong Province of South China

Huang Bingchao[1]

Groundnut is a major oilseed crop in Guangdong Province of South China. The climate of Guangdong is subtropical with an average annual temperature of 17–23°C and rainfall of 1500–2300 mm. Hence there was a serious problem with pests and diseases on groundnut and yield losses account for 20–30%.

In the past 35 years, scientists of the Guangdong Academy of Agricultural Sciences and the South China Agricultural University have done substantial research on groundnut diseases such as rust (*Puccinia arachidis*), early leaf spot (*Cercospora arachidicola*), late leaf spot (*Phaeoisariopsis personata*), bacterial wilt (*Pseudomonas solanacearum*), peanut clump, and root rot (*Sclerotium rolfsii*); on insect pests such as aphids (*Aphis craccivora*), thrips (*Thrips palmi*), tobacco cutworm (*Spodoptera litura*), and soil insects; and on peanut nematode root knot (*Meloidogyne* sp), and have evolved some methods to overcome some of these constraints.

The compound measure of integrated pest management (IPM) for groundnut in the province includes a) identification of resistant sources, b) cultural control, and c) chemical control. Identifying varietal resistance is the key factor for groundnut rust and bacterial wilt and breeders have developed some resistant varieties for these two major diseases. Cultural control is found to be very effective in reducing yield losses. This includes crop rotation, a good irrigation system, optimum sowing population, manure, and fertilizers, and use of herbicides to control weeds. The cropping system of groundnut, rice (*Oryza sativa*), and sweet potato (*Ipomoea batatas*) or wheat (*Triticum* sp) has had a remarkable effect in controlling the nematode root knot, bacterial wilt, and leaf spot diseases in the wetland areas of Guangdong. For chemical control, the emphasis is on forecasting the occurrence of major insect pests and diseases followed by effective chemical control. Giving IPM training to the farmers and agricultural technical members of the province by the plant protection specialists has greatly helped effective implementation of IPM.

The future research direction includes new technology for forecasting the disease epidemics, especially rust, methods to save and use natural enemies, development of resistant sources, and improved breeding technologies.

Revue des ennemis et maladies de l'arachide et application de la lutte intégrée dans la province de Guangdong, sud de la Chine

L'arachide est une principale culture oléagineuse de la province de Guangdong, sud de la Chine. Le climat de Guangdong est sub tropical, avec une température moyenne annuelle de 17–23°C, et une pluviosité de 1500–2300 mm. C'est pourquoi, un problème grave est posé pas les ennemis et maladies de l'arachide et les pertes de rendement atteignent 20–30%.

Au cours des 35 dernières années, les scientifiques de l'Académie des sciences agricoles du Guangdong et de l'Université agricole du sud de la Chine ont fait des recherches importantes sur les maladies de l'arachide, comme la rouille (*Puccinia arachidis*), la tache foliaire précoce (*Cercospora arachidicola*), la tache foliaire

1. Entomologist, Plant Protection Research Institute, Guangdong Academy of Agricultural Sciences, Guangzhou, Guangdong Province, People's Republic of China.

tardive (*Phaeoisariopsis personata*), le flétrissement bactérien (*Pseudomonas solanacearum*), le rabougrissement de l'arachide, la pourriture des racines (*Sclerotium rolfsii*); et sur des insectes ennemis comme les aphidés (*Aphis craccivora*), des thrips (*Thrips palmi*), le vers gris du tabac (*Spodoptera litura*), et les insectes édaphiques; ainsi que sur l'anguillule des racines (*Meloidogyne* sp) et on a mis au point certaines méthodes pour surmonter certaines de ces contraintes.

L'ensemble des mesures de lutte intégrée contre les ennemis de l'arachide dans la province comprend a) l'identification des sources de résistance, b) la lutte culturale, et c) la lutte chimique. Le facteur clef consiste à identifier la résistance variétale contre la rouille de l'arachide et le flétrissement bactérien, et les sélectionneurs ont mis au point certaines variétés résistantes à ces deux principales maladies. La lutte culturale est très efficace pour réduire les pertes de rendement. Cela comprend la rotation des récoltes, un bon système d'irrigation, un peuplement optimum aux semis, la fumure, les engrais, et l'usage d'herbicide pour lutter contre les adventices. Le système de culture de l'arachide, du riz (*Oryza sativa*), et la patate douce (*Ipomoea batatas*), ou du blé (*Triticum* sp) ont un effet remarquable pour lutter contre l'anguillule des racines, le flétrissement bactérien, et la tache foliaire dans les zones humides de Guangdong. La lutte chimique insiste pour prévoir l'apparition des principaux insectes ennemis et maladies, suivie par une lutte chimique efficace. Assurer une formation de la lutte intégrée aux cultivateurs et aux techniciens agricoles de la province par les spécialistes de la protection de la culture a aidé largement à appliquer la lutte intégrée.

La prochaine orientation de la recherche comprend une technologie nouvelle de prévision des épidémies de maladies, spécifiquement la rouille, des méthodes pour protéger et utiliser les prédateurs naturels des ennemis, le développement de sources de résistance, et l'adoption de technologie de sélection améliorée.

Incidence and Management of Groundnut Thrips Causing Bud Necrosis Disease in the Southern Region of Sri Lanka

Rohan Rajapakse[1] and K.W. Jayasena[2]

Several field experiments were conducted at the Regional Research Station, Angunakolapelessa, and at the Faculty of Agriculture, Mapalana, on incidence and management of thrips (*Frankliniella schultzei)* during 1990 and 1991. The maximum monthly trap catches of thrips species were recorded in September and the lowest in January and February. Intercropping with other cereals resulted in a low incidence of thrips. The insecticide Thiodicarb was found to be effective in controlling nymphs of *F. schultzei.*

Incidence et maîtrise du thrips de l'arachide qui provoque la maladie de la nécrose du bourgeon dans la région sud de Sri Lanka

Différentes expériences sur le terrain ont été effectuées à la Station régionale de recherche d'Angunakolapelessa, et à la Faculté d'agriculture de Mapalana, sur l'incidence et la lutte contre le thrips (*Frankliniella schultzei*) en 1990–91. Les prises maximum mensuelles par les pièges d'espèces de thrips ont été mentionnées en septembre et les plus faibles en janvier et février. Une culture associée à une autre céréale réduisait l'incidence du thrips. L'insecticide Thiodicarbe a été efficace pour lutter contre les nymphes de *F. schulzei.*

1. Senior Lecturer (Entomology), Dean, Faculty of Agriculture, University of Ruhuna, Mapalana, Kamburupitiya, Sri Lanka.
2. Research Officer (Virology), Regional Research Station, Angunakolapelessa, Sri Lanka.

Resistance to *Spodoptera litura* Defoliation in *Arachis* Species

P.C. Stevenson[1], D.E. Padgham[1], J.A. Wightman[2], and J.P. Moss[2]

Extensive screening of groundnut and *Arachis* spp has resulted in identification of limited resistance to *Spodoptera litura* defoliation in the former. However, it is hoped that cytogenetic techniques will be applied to transfer resistance genes from those wild *Arachis* that show high levels of antibiosis to *S. litura* into groundnut varieties.

Potential for resistance to *S. litura* was assessed in 15 wild *Arachis* species. Whole leaves were screened for larval acceptability, weight gain, and survival. Species showing the highest levels of resistance in whole-plant bioassays were then chemically fractionated in a series of polar and nonpolar solvents, the fractions being freeze-dried and incorporated into artificial diets. Those diets showing the inhibition of larval development were further assayed by a range of chromatographic techniques. Of the species tested, maximum developmental inhibition occurred when feeding on an extract of *A. paraguariensis*. HPLC analysis of this fraction identified three isomers of caffeol quinic acid. Future studies will identify resistance in *A. hypogaea* × *Arachis* spp hybrids and the chemicals responsible. This research has established practical principles from which breeding for pest resistance, including the intractable problem of *Helicoverpa*, can be developed.

Résistance à la défoliation par *Spodoptera litura* des espèces d'*Arachis*

Un criblage étendu de l'arachide et d'*Arachis* spp a permis d'identifier une résistance limitée à la défoliation par *Spodoptera litura* chez l'arachide. Toutefois, on espère que des techniques phytogénétiques seront appliquées pour transférer aux variétés d'arachide les gènes de résistance des *Arachis* sauvages qui manifestent une forte antibiose à *S. litura*.

Le potentiel de résistance à *S. Litura* a été évalué dans 15 espèces sauvages d'*Arachis*. Des feuilles entières ont été criblées quant à l'acceptabilité par les larves, au gain de poids et à la survie. Des espèces montrant le niveau le plus élevé de résistance dans le titrage du plant entier ont alors été fractionnées chimiquement dans une série de solvants polaires et non polaires, les fractions étant lyophilisées et incorporées dans des régimes artificiels. Les régimes qui manifestaient une inhibition du développement larvaire ont alors été titrés par une gamme de techniques chromatographiques. Sur les espèces essayées l'inhibition maximum se produit lors de l'alimentation par un extrait de *A. paraguariensis*. L'analyse HPLC de cette fraction identifiait trois isomères d'acide quinique cafféol. De nouvelles études indentifieront la résistance chez les hybrides de *A. hypogaea* × *Arachis* spp et les produits chimiques qui en sont la cause. Cette recherche a déterminé des principes pratiques pour lesquels la sélection pourra être développée en vue de la résistance aux ennemis, y compris le problème insoluble d'*Helicoverpa*.

1. Higher Scientific Officer and Senior Scientific Officer, Natural Resources Institute, Central Avenue, Catham Maritime, Kent ME4 4TB, U.K.
2. Principal Entomologist and Principal Cell Biologist, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh 502 324, India.

Groundnut Resistance to *Aphis craccivora*, Vector of Groundnut Rosette Virus

F.M. Kimmins[1], R.J. Grayer[2], J.A. Wightman[3], and G.V. Ranga Rao[3]

Diseases such as the groundnut rosette virus transmitted by aphids (*Aphis craccivora*) can be a major constraint on groundnut production. Resistance to this vector has been identified by ICRISAT scientists in the genotype ICG 5240, and a collaborative project with the Natural Resources Institute (NRI), Overseas Development Administration (ODA), U.K, has established the mechanism of resistance.

Field and laboratory studies showed that aphid development and reproduction was significantly lower on ICG 5240 when compared with aphids on a susceptible check ICG 221. Electronic studies of aphid feeding showed that the aphids located the phloem (the feeding site) in the resistant genotype as successfully as in the susceptible genotype. However, the mean duration of phloem feeding on the resistant genotype was 50% less than on the control.

Chemical analysis indicated that a high concentration of the condensed tannin, procyanidin, in ICG 5240 might be disrupting prolonged ingestion. A strong negative correlation between the procyanidin concentration and aphid development has been demonstrated in seven groundnut genotypes.

Résistance de l'arachide à *Aphis craccivora*, vecteur du virus de la rosette de l'arachide

Des maladies telles que la virose de la rosette de l'arachide, transmise par des aphidés (*Aphis craccivora*) peuvent être une contrainte très sérieuse de la production arachidière. La résistance aux vecteurs a été identifiée par les scientifiques de l'ICRISAT dans le génotype ICG 5240 et un projet en collaboration avec l'Institut des ressources naturelles (NRI), à l'Administration du développement d'outre-mer (ODA) du Royaume Uni, a déterminé le mécanisme de la résistance.

Des études sur le terrain et en laboratoire ont montré que le développement des aphidés et leur reproduction étaient nettement plus faibles sur ICG 5240 en comparaison avec les aphidés sur un témoin sensible, ICG 221. Des études électroniques de l'alimentation des aphidés montrent que les aphidés localisaient le phloème (le lieu d'alimentation) du génotype résistant aussi facilement que sur le génotype sensible. Toutefois, la durée moyenne d'alimentation sur le phloème du génotype résistant était inférieure de 50% à celle du témoin.

L'analyse chimique a indiqué qu'une forte concentration du tannin condensé, procyanidin, dans ICG 4240 pourrait déranger une ingestion prolongée. Une forte corrélation négative entre la concentration du procyanidine et le développement des aphidés a été démontrée dans sept génotypes d'arachide.

1. Higher Scientific Officer, Natural Resources Institute, Central Avenue, Catham Maritime, Kent ME4 4TB, U.K.
2. Research Associate, University of Reading, Shinfield, Reading, Berkshire RG2 9AD, U.K.
3. Principal Entomologist and Entomologist, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh 502 324, India.

Assessment of Need Based Monocrotophos Applications for the Control of Major Pests of Groundnut

S.A. Ghorpade and R.B. Sonawane[1]

In a 2-year experiment conducted at the Oilseeds Research Station, Jalgaon, two spray applications of 0.05% monocrotophos at 30 and 60 days after germination proved most effective and economical for the control of aphids (*Aphis craccivora*), jassids (*Empoasca kerri*), thrips (*Thrips palmi*), leaf miner (*Aproaerema modicella*), and *Spodoptera* on groundnut. This treatment gave an additional income of Rs 1755 ha^{-1} compared to the untreated control, with a benefit/cost ratio of 4.4.

Evaluation d'épandage de monocrotophos selon les besoins pour la lutte contre les principaux ennemis de l'arachide

Au cours d'une expérience de deux ans effectuée à la Station de recherches de l'huile sur les plantes oléagineuses à Jalgaon, deux épandages par pulvérisations de 0,05% monocrotophos à 30 et 60 jours après la germination, ont donné d'excellents résultats pour la lutte contre les aphidés (*Aphis craccivora*), jassidés (*Empoasca kerri*), thrips (*Thrips palmi*), la mineuse des feuilles (*Aproaerema modicella*), et *Spodoptera* sur l'arachide. Par ce traitement on a augmenté le rendement des producteurs de Rs 1744 ha^{-1} en comparaison avec le témoin non traité avec un ratio avantage/coût de 4,4.

1. Entomologist and Senior Scientist, Oilseeds Research Station, Mahatma Phule Agricultural University, Jalgaon 425 001, Maharashtra, India.

Recent Advances in Management of the Crop Growth Variability in Groundnut

F. Waliyar[1], B.J. Ndunguru[1], and S.B. Sharma[2]

One of the constraints to groundnut production in the sandy soils of Niger is crop growth variability. Within the same field, plants vary considerably in height, growth, and productivity.

Earlier studies on crop growth variability indicated that nematodes and peanut clump virus played an important role in the crop growth variability problem at the ICRISAT Sahelian Center (ISC), Sadoré, Niger, and carbofuran application significantly increased pod yield.

Field trials were conducted during the 1989 and 1990 rainy seasons and 1989/90 and 1990/91 dry seasons, to study crop growth variability. A split-plot arrangement of treatments was used with carbofuran as main plots and lime as subplots. Two rates of carbofuran (0 and 10 kg ha^{-1} a.i.) and four rates of lime (0, 5, 10, and 20 t ha^{-1}) as dolomite containing 34% Ca and 20% Mg were applied prior to sowing. Soil pH and exhangeable aluminium were measured at sowing, one month after sowing, and at harvest.

In the 1989 rainy season, the carbofuran treatment increased the pod yield. Lime application did not change the pH and Al^{+++} content in the soil and did not increase groundnut yield. In the 1990 rainy and 1990/91 dry season, however, the application of 10 t ha^{-1} of lime increased pH, decreased Al^{+++}, improved crop growth, and increased the yield of groundnut to the same level as was achieved by the carbofuran treatment. Lime did not affect the nematode population, which was reduced by carbofuran. The important role of aluminium toxicity will be taken into account in the development of a practical management system for the control of crop growth variability.

Récents progrès de la gestion de la variabilité de la croissance de l'arachide

L'une des contraintes de la production arachidière dans les sols sablonneux du Niger, c'est la variabilité de croissance de la culture. Dans le même champ, des plants varient considérablement quant à leur hauteur, leur croissance, et leur productivité.

Des études précédentes sur la variabilité de la croissance de la culture ont indiqué que les nématodes et le virus racinaire de l'arachide jouent un rôle important dans le problème de variabilité de croissance de la culture au Centre sahélien de l'ICRISAT, à Sadoré, Niger, et qu'un épandage de carbofuran augmente nettement le rendement de gousses.

Des essais sur le terrain ont été entrepris pendant les saisons des pluies de 1989 et 1990 et les saisons sèches de 1989/90 et 1990/91, pour étudier la variabilité de croissance de la culture. Un dispositif split-plot de traitement a été utilisé avec le carbofuran sur les parcelles principales et un chaulage sur les sous-parcelles. Deux taux de carbofuran (0 et 10 kg ha^{-1} m.a) et 4 taux de chaulage (0, 5, 10, et 20 t ha^{-1}) sous forme de dolomite contenant 34% de Ca et 20% de Mg ont été appliqués avant les semis. Le pH du sol et l'aluminium échangeable ont été mesurés au semis, un mois après le semis et à la récolte.

1. Principal Groundnut Pathologist and Principal Groundnut Agronomist, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Sahelian Center, Sadoré, Niger.

2. Plant Nematologist, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh 502 324, India.

Au cours de la saison des pluies de 1989, le traitement de carbofuran a augmenté le rendement en gousses. Le chaulage n'a pas changé le pH et la teneur en Al^{+++} du sol et n'a pas augmenté le rendement d'arachide. Pendant la saison des pluies de 1990 et la saison sèche de 1990/91, toutefois, l'épandage de 10 t ha^{-1} de chaux a augmenté le pH, diminué Al^{+++}, amélioré la croissance de la culture et augmenté le rendement d'arachide au même degré que le traitement de carbofuran. Le chaulage n'a pas affecté la population de nématodes, qui a été réduite par le carbofuran. Le rôle important de la toxicité aluminique sera pris en considération pour le développement d'un système de gestion pratique en vue de maîtriser la variabilité de croissance de la culture.

A Practical Approach to the Remediation of Aflatoxin-contaminated Crops and Prevention of Aflatoxicosis in Animals: Selective Chemisorption of Aflatoxins by Phyllosilicate Clays

T.D. Phillips, B.A. Clement, A.B. Sarr, and J.A. Ellis[1]

A phyllosilicate clay, hydrated sodium calcium aluminosilicate (HSCAS), was shown to tightly bind aflatoxins and prevent aflatoxicosis in animals. In further studies, HSCAS effectively removed aflatoxins from contaminated milk and groundnut oil. Compounds with one or more of the functional groups in common with aflatoxin were reacted with HSCAS in vitro in an attempt to elucidate the mechanism of tight binding (or chemisorption). The β-dicarbonyl system was found to be essential for chemisorption by HSCAS. Diffuse reflectance infrared Fourier transform spectroscopy (DRIFTS) was used to examine sorbed pellets of aflatoxin-HSCAS. DRIFTS clearly showed dramatic shifts of the C=O absorptions that were identical to those known to arise from metal-acetylacetonates. These findings indicate that the molecular mechanism of aflatoxin chemisorption may involve the chelation of the β-dicarbonyl moiety in aflatoxin with metal ions in HSCAS. A chemisorption index (C_α) was developed allowing direct comparison of various phyllosilicate clays with HSCAS. C_αs were determined by HPLC analysis of extracts of the supernatants and sorbed pellets (exhaustively extracted with methanol, chloroform, and hexane). Comparison of the C_αs of various classes of compounds with spectral data (DRIFTS) supported the proposed mechanism of chemisorption. With knowledge of the mechanism, it has been possible to chemically activate certain African clay samples and enhance their propensity for aflatoxins.

Méthode pratique de remédier à la présence d'arachides contaminées par l'aflatoxine et la prévention de l'aflatoxicose chez les animaux: chemi-sorption sélective d'aflatoxine par les argiles à phyllosilicates

Une argile à phyllosilicate (HSCAS) a démontré qu'elle peut lier fermement les aflatoxines et empêcher l'aflatoxicose chez les animaux. Au cours d'études plus poussées, HSCAS a éliminé effectivement les aflatoxines de lait contaminé et d'huile d'arachide. Des composés à un ou plusieurs groupes fonctionnels en commun avec l'aflatoxine ont réagi avec HSCAS in vitro dans un effort pour élucider le mécanisme de liens étroits (ou chemi-sorptions). Le système de β-discarbonyl est essentiel à la chemi-sorption par HSCAS. La spectroscopie Fourier à réflectance diffuse d'infra-rouges (DRIFTS) a servi à examiner les granulés enrobés des HSCAS à l'aflatoxine. Les DRIFTS manifestent clairement des dérives évidentes des absorptions C=O que l'on savait se produire dans le cas de l'acétylacétonate de métal. Ces constatations indiquent que le mécanisme moléculaire de la chemi-sorption d'aflatoxine, peut impliquer la chelation de la moitié de β-dicarbonyl dans l'aflatoxine avec des lésions métalliques dans HSCAS. Un indice de chemi-sorbtion C_α a été mis au point permettant une comparaison directe de diverses argiles phyllosilicatées avec HSCAS. Des C_α ont été déterminés par un indice d' HPLC d'extraits des éléments surnageant et sorbé (extraits exhaustivement au moyen des méthanol, chloroforme et hexane). Une comparaison du C_α des différentes classes des coordonnées à données spectrales (DRIFTS) a appuyé le mécanisme proposé de chemi-sorption. Le mécanisme étant connu, il a été possible d'activer chimiquement certains échantillons d'argile africaine, et de rehausser leur attraction pour les aflatoxines.

---

1. Professor of Toxicology, Research Scientist, and Graduate Students, College of Veterinary Medicine, Texas A&M University, College Station, TX 77843-4468, USA.

Supported by USAID Grant no. DAN 4048-G-00-0041-00, the Englehard Corporation, Cleveland, Ohio and TAES, Project H-6215.

The Aflatoxin Problem Can Be Overcome

J.I. Keenan[1] and G.P. Savage[2]

The preharvest invasion of groundnuts by *Aspergillus flavus* and the subsequent production of toxic metabolites is a constant feature of groundnut production. Groundnut hulls are often invaded by *A. flavus* during growth in the soil. Adequately irrigated plants have natural protective mechanisms that respond to invasion. Drought stress during the last 4 to 6 weeks of the growing season opens a "window of susceptibility", which allows fungal growth and the subsequent production of aflatoxin. Once invaded by the fungus, the potential also exists for aflatoxin production during drying, transport, and storage of kernels. Kernel moisture content and the environmental temperature are the most important parameters. The pods should be sun or artificially dried to <9% moisture as rapidly as possible prior to storage. Groundnuts that are stored in the shell are much less likely to be contaminated in storage by the seed testa.

Aflatoxin can affect humans directly via the food chain. Importing nations specify maximum tolerance levels for aflatoxin in human and animal feeds, which reduces the risk to the consumer. Aflatoxin removal has to be tailored to the product involved, so increasing costs and ultimately reducing the nutritive value. For consumers in producing countries, the effects of the toxin are more difficult to evaluate. Apart from acute effects, the toxin has been implicated as a cofactor in a number of chronic conditions, the most controversial of these being primary liver cancer. If greater consideration was given to the predisposing factors, the problem of aflatoxin contamination would not be such a major economic and public health problem.

Le problème de l'aflatoxine peut être surmonté

L'invasion pré-récolte de l'arachide par *Aspergillus flavus* et la production qui en résulte de méthabolites toxiques est un aspect constant de la production arachidière. Des coques d'arachides sont souvent envahies par *A. flavus* pendant la croissance souterraine. Des plants adéquatement irrigués ont un mécanisme naturel de protection qui répond à l'invasion. Le stress de la sécheresse pendant les 4 à 6 dernières semaines de la saison de croissance ouvre "une fenêtre de sensibilité" qui permet la croissance de champignons et la production ultérieure d'aflatoxine. Une fois que l'arachide est envahie par le champignon, il existe un potentiel de contamination par l'aflatoxine pendant le séchage, le transport et le stockage des grains. La teneur en humidité des grains et la température ambiante sont les paramètres les plus importants. Les gousses doivent être séchées au soleil ou artificiellement pour réduire l'humidité à 9 % aussi rapidement que possible avant le stockage. Les arachides qui sont stockées en coque ont beaucoup plus de chance d'être contaminées pendant le stockage par les germes des grains.

L'aflatoxine peut affecter les consommateurs humains directement ou par la chaîne alimentaire. Les pays importateurs spécifient un niveau maximum de tolérance d'aflatoxine dans les produits destinés à la consommation humaine et aux produits d'affouragement du bétail, ce qui réduit les risques pour le consommateur. L'élimination de l'aflatoxine doit être élaborée selon le produit en jeu, ce qui augmente les coûts et en fin de compte réduit la valeur nutritive. En dehors de ses effets aigus la toxine a été considérée comme un co-facteur d'un certain nombre d'états chroniques, le rôle le plus controversable était le cancer primaire du foie. Si on se préoccupait davantage des facteurs prédisposants, le problème de la contamination par l'aflatoxine ne serait pas un problème de santé publique et économique aussi grand.

1. Research Technologist, Department of Medicine, Christchurch School of Medicine, Riccarton Avenue, Christchurch, New Zealand.
2. Senior Lecturer, Department of Biochemistry and Microbiology, Lincoln University, P.O. Box 84, Canterbury, New Zealand.

Intercropping and Weed Management

Integrated Weed Management – An Efficient Method of Groundnut Weed Control

A. Ramakrishna[1]

Field experiments were conducted under rainfed conditions on groundnut to test the comparative efficacy of preemergence herbicides, metolachlor and pendimethalin, applied separately and in combination with hand weeding. Preemergence applications of pendimethalin or metolachlor (1.0 kg a.i. ha^{-1}) were equivalent to a single hand weeding at 30 days after sowing (DAS). Integration of herbicide and hand weeding at 30 DAS gave consistent and effective weed control and higher pod yields over 2 years.

Malherbologie – méthode efficace de lutte contre les adventices de l'arachide

Des expériences sur le terrain ont été effectuées dans des conditions pluviales sur l'arachide pour tester l'efficacité comparative d'herbicides prélevée, le métolachlore et le pendiméthaline, appliqués séparément et en combinaison avec un sarclage manuel. Les épandages prélevés de pendiméthaline ou de métolachlore (1,0 kg m.a. ha^{-1}) étaient équivalents à un seul sarclage manuel à 30 jours après les semis (JAS). L'intervention d'herbicide et de sarclage manuel à 30 JAS a donné des résultats constants et efficaces de malherbologie et des rendements plus élevés en gousses pendant two ans.

1. Agronomist, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh 502 324, India.

Studies on Intercropping of Pulses and Oilseeds in Kharif Groundnut

K.P. Hatkar, M.P. Deshmukh, and Y.M. Shinde[1]

An experiment conducted for 3 years (1987–89) at Jalgaon in the rainy season revealed that 3:1 or 6:2 row proportions were the most profitable systems of intercropping groundnut and red gram (*Cajanus cajan*). The highest benefit/cost ratio of 3.19 was observed in 3:1 proportion with red gram, followed by the benefit/cost ratio of 3.15 in 6:2 row proportion. Significantly higher values of land equivalent ratio (LER) also indicated efficient utilization of land by groundnut–red gram combination as compared with intercropping groundnut with black gram (*Vigna mungo*), sesame (*Sesamum indicum*), or sunflower (*Helianthus annuus*).

Etudes sur la culture associée de légumineuses et de plantes oléagineuses dans la culture arachidière de Kharif

L'expérience effectuée pendant trois ans (1987–89) à Jalgaon, en saison des pluies, a révélé que les proportions 3:1 ou 6:2 dans les rangées étaient les plus profitables dans le cadre de l'association de l'arachide et du pois d'Angole (*Cajanus cajan*). Le ratio avantage/coût le plus élevé, de 3,19 a été remarqué selon une proportion de 3:1 avec le pois d'Angole, suivi par le ratio avantage/coût de 3,15 dans la proportion de rangées à 6:2. Des valeurs nettement plus élevées de ratio terre équivalent (LER) ont indiqué aussi une utilisation efficace de la terre par la combinaison arachide-pois d'Angole en comparaison avec la culture associée arachide avec le pois mungo (*Vigna mungo*), le sésame (*Sesamum indicum*) et le tournesol (*Helianthus annuus*).

1. Agronomist, Senior Research Assistant, and Senior Scientist, Oilseeds Research Station, Mahatma Phule Agricultural University, Jalgaon 425 001, Maharashtra, India.

Processing and Products

Development of Threshing and Shelling Systems Appropriate for Small Groundnut Farmers in the Caribbean

B.R. Cooper[1], M.S. Chinnan[2], A.K. Sinha[3], U. Wilson[4], and G. Muller[5]

Groundnut production in the Caribbean is primarily on small farms of 1 ha or less. Most operations, except primary tillage, are done by hand. This includes the labor-intensive operations of shelling seeds by hand prior to sowing and the whole of the harvesting operations of lifting, threshing, and drying the seeds. The high labor input reduces the profitability of the crop, especially under risk-prone, rainfed systems, and limits the area that the farm family can manage.

As part of the Groundnut Collaborative Research Support Program activities in the Caribbean carried out by the Caribbean Agricultural Research and Development Institute (CARDI) and the University of Georgia, design, fabrication, testing, and evaluation of simple mechanical aids to shelling and threshing have been carried out since 1988. Hand-operated shellers and small motor-driven threshers have been evaluated on-farm in Belize, Jamaica, and Antigua. Considerable emphasis has been placed on technology transfer and the Program has worked closely with farmers and the Extension Divisions of the various Ministries of Agriculture.

Adoption of shellers has been good and, where cooperatives exist, interest in the threshers has been encouraging. Further work to commercialize the designs and incorporate locally available components as well as to assist farmers organizations will continue.

Mise au point de systèmes de battage et d'écossage qui conviennent aux petits producteurs dans les Caraïbes

La production d'arachide aux Caraïbes se fait essentiellement dans de petites exploitations de 1 hectare ou moins. La plupart des opérations, sauf les labours primaires se font manuellement. Cela comporte des opérations ergastives de l'écossage manuel des semences, avant les semis et de l'ensemble des opérations de récolte, l'arrachage, le battage, et le séchage des grains. L'importance de main-d'oeuvre réduit la rentabilité de la culture, surtout dans les systèmes pluviaux qui courent beaucoup de risques et cela limite la superficie qu'une famille de cultivateur peut gérer.

Dans le cadre des activités de programmes collaboratifs d'appui aux recherches dans les Caraïbes, entrepris par l'Institut de recherche du développement agricole des Caraïbes (CARDI) et l'Université de Georgie, la conception, la fabrication, les essais et l'évaluation de moyens mécaniques simples pour écosser et battre ont été entrepris depuis 1988. Des écosseuses manuelles et de petites batteuses à moteur ont été évaluées sur les exploitations à Belize, à la Jamaïque,et à Antigua. On a beaucoup insisté sur le transfert de technologie et le programme a travaillé en liaison étroite avec les cultivateurs et divisions de vulgarisation des divers Ministères de l'agriculture.

L'adoption d'écosseuses a été bonne et, là où il existe des coopératives, l'intérêt à l'égard de ce système a été encourageant. Davantage de travaux seront effectués pour commercialiser les conceptions et incorporer les éléments disponibles sur place, ainsi que pour aider les organisations de cultivateurs.

1. Systems Agronomist, Caribbean Agricultural Research and Development Institute, P.O. Box 766, Friars Hill, St. John's, Antigua, West Indies.
2. Professor, Department of Food Science and Technology, University of Georgia, Griffin, GA 30223, USA.
3. Entomologist, Caribbean Agricultural Research and Development Institute, P.O. Box 2, Forest Drive, Belmopan, Belize.
4. Agricultural Research Engineer, Caribbean Agricultural Research and Development Institute, UWI-Mona Campus, Kingston 7, Jamaica, West Indies.
5. Leader, Crop Production Program, Caribbean Agricultural Research and Development Institute, University Campus, St. Augustine, Trinidad, West Indies.

Development of Drying and Storage Systems Appropriate for Small Groundnut Farmers in the Caribbean

U. Wilson[1], A.K. Sinha[2], Tal Oz-Ari[3], M.S. Chinnan[4], and B.R. Cooper[5]

Drying and storage of groundnuts in the Caribbean is done out of habit or necessity, with little awareness of or appreciation for the true bearing these operations have on consumer health, groundnut quality and marketability, and hence income to the small farmer.

All drying is by sun, with the groundnuts spread in a single layer over canvas, zinc sheets, or concrete floors. In recent times, rising incidence of theft has been forcing many farmers to forego windrowing, hence groundnuts are threshed and dried immediately after harvesting. Drying is done 5 to 6 hours per day for 4 to 5 days, depending on the weather and the farmer. Storage facilities, often kitchens, living rooms, or bedrooms, are improperly ventilated and offer inadequate protection from moisture and pests.

These practices result in groundnuts of poor and inconsistent quality. Consequently, processors who can provide a stable market are reluctant to purchase farmers' produce. In response to this situation, the Caribbean Agricultural Research and Development Institute (CARDI), the Peanut CRSP, and the Ministries of Agriculture have collaborated to introduce technology for improving farmers' groundnut stock. Storage and low cost mechanical drying facilities have been set up in Belize and Jamaica, for purposes of demonstration, economic evaluation, research on storage and aflatoxin, and modeling of community storage and drying systems.

Mise au point de séchage et de stockage convenant au petit producteur d'arachide dans les Caraïbes

Le séchage et le stockage des arachides dans les Caraïbes se font par habitude ou par nécessité, sans bien comprendre ni évaluer les effets de ces opérations sur la santé des consommateurs, la qualité de l'arachide et sa commerciabilité, et donc le revenu des petits cultivateurs.

Tout le séchage se fait au soleil, les arachides étant étalées dans une couche unique sur toile, feuille de zinc ou béton. Récemment, l'incidence croissante des vols a forcé bien des cultivateurs à renoncer à l'andainage; donc les arachides sont battues et séchées immédiatement après la récolte. Le séchage se fait pendant 5 à 6 heures par jour pendant 4 à 5 jours selon les conditions atmosphériques et le cultivateur. Les possibilités de stockage, souvent dans des cuisines, des pièces de séjour, ou des chambres à coucher, ne sont pas suffisamment ventilées et ne protègent guère de l'humidité et des ennemis.

Ces méthodes provoquent la production d'arachides de qualité faible et irrégulière. Par conséquent, les transformateurs qui peuvent fournir un marché stable, hésitent à acheter les produits des cultivateurs. En réponse à cet état de chose, l'Institut de recherche du développement agricole des Caraïbes (CARDI), la Peanut CRSP, et les Ministères de l'agriculture ont collaboré pour introduire une technologie permettant d'améliorer le stock d'arachide des cultivateurs. Des dispositifs de stockage et un mécanisme de dessiccation à coût réduit ont été inaugurés à Belize et à la Jamaïque, aux fins de démonstration, d'évaluation économique, de recherche sur le stockage et l'aflatoxine et de modélisation des systèmes de stockage et de séchage des villages.

1. Agricultural Research Engineer, Caribbean Agricultural Research and Development Institute, P.O. Box 113, U.W.I., Mona Campus, Kingston 7, Jamaica, West Indies.
2. Entomologist, Caribbean Agricultural Research and Development Institute, P.O. Box 2, Forest Drive, Belmopan, Belize.
3. Agricultural Research Engineer, Department of Food Science and Technology, University of Georgia, Griffin, GA 30223, USA.
4. Professor, Department of Food Science and Technology, University of Georgia, Griffin, GA 30223, USA.
5. Systems Agronomist, Caribbean Agricultural Research and Development Institute, P.O. Box 766, Friars Hill, St. John's, Antigua, West Indies.

Consumer Evaluation of Sensory Quality of Groundnut-supplemented Chinese-type Noodles

A.V.A. Resurreccion[1], P. Chompreeda[2], V. Haruthaithanasan[2], and L.R. Beuchat[1]

In Asia, many consumers prefer clear, pale yellow noodles, free of any darkening or discoloration, and having sufficient firmness to give a clean bite without being tough. Studies on the development of groundnut-supplemented Chinese-type noodles resulted in products with sensory quality characteristics that are acceptable when a formulation containing a maximum level of 15% groundnut flour was used. During the early development stages, supplementation of noodles with 10% groundnut flour resulted in significantly different sensory scores for color lightness and texture firmness but not in flavor intensity. When laboratory production of the noodles was scaled up to a commercial process, the equipment was able to handle formula levels of groundnut flour up to 11.5%.

Evaluation de la qualité sensorielle de nouilles de type chinois, enrichies par arachide

En Asie, bien des consommateurs préfèrent les nouilles translucides, jaune pâle, exemptes de tout noircissement ou de toute coloration et qui sont assez fermes sous la dent, sans être dures. Des études sur la mise au point de nouilles de type chinois, enrichies par arachide, ont mené à des produits qui ont des caractéristiques de qualité sensorielle acceptables lorsqu'une formule comportant au maximum 15% de farine d'arachide était utilisée. Pendant les premières étapes du développement, l'enrichissement de nouilles au moyen de 10% de farine d'arachide a provoqué des réactions sensorielles très différentes en ce qui concerne la couleur et la fermeté de la texture, mais non pas quant à l'intensité de la saveur. Lorsque la production en laboratoire des nouilles a été transformée pour en faire un processus commercial, le matériel a pu appliquer des niveaux de formules de farine d'arachide allant jusqu'à 11,5%.

1. Associate Professor and Professor, Food Safety and Quality Enhancement Laboratory, Department of Food Science and Technology, University of Georgia, Griffin, GA 30223–1797, USA.
2. Principal Investigator (Peanut CRSP) and Head of Department, Department of Product Development, Faculty of Agro-Industry, Kasetsart University, 50 Paholyothin Road, Bangkok 10900, Thailand.

Supported by the United States Agency for International Development, Peanut Collaborative Research Support Program.

Present Status and Future Prospects of Groundnut Processing in India

M.C. Shamanthaka Sastry[1]

The edible oil economy in India is very much dependent on the production of groundnut in view of its high contribution to the total edible oil pool. However, the oil and cake obtained by conventional procedures are of poor quality. The quality deterioration is mainly due to improper drying and the presence of damaged kernels and fungal infected seeds high in aflatoxin.

The Central Food Technological Research Institute (CFTRI) has done considerable research and development (R&D) on various aspects relating to modernizing the oilseed milling, with a view to obtaining good quality oil and protein-rich cake free from aflatoxin. The edible quality meal has been utilized in various food formulations but few products are commercially exploited.

Although considerable R&D data on various aspects of groundnut processing are available, due attention has not be given to: a) postharvest technology and conservation, b) processing of newer varieties in terms of quality parameters of oil and cake, c) the possible use of groundnut meal as pulse extenders (in view of the deficit production of pulses in the country), and d) production of partially defatted groundnut seeds for export.

Bilan actuel et prévisions du traitement de l'arachide en Inde

L'économie de l'huile comestible en Inde dépend beaucoup de la production d'arachide, en raison de sa très forte contribution au total des réserves d'huile alimentaire. Toutefois, l'huile et le tourteau obtenus par des méthodes conventionnelles sont de faible qualité. La détérioration de qualité résulte surtout d'un séchage insuffisant et de la présence de grains endommagés et de grains infectés par des champignons riches en aflatoxine.

L'Institut central de recherche technologique alimentaire (CFTRI) a fait beaucoup de travail sur la recherche et le développement en ce qui concerne différents aspects de la modernisation du broyage des grains lors de l'extraction d'huile, en vue d'obtenir une huile de meilleure qualité et un tourteau riche en protéines et exempt d'aflatoxine. La farine de qualité comestible a été utilisée dans différentes formules alimentaires mais peu de projets sont commercialement exploités.

Bien que l'on dispose d'une masse considérable de données sur les recherches et le développement de divers aspects de traitement de l'arachide, on ne s'est pas suffisamment préoccupé de a) de la technologie et de la conservation post-récolte, b) du traitement de nouvelles variétés en ce qui concerne les paramètres de l'huile et du tourteau, c) l'usage possible de farine d'arachide pour enrichir les légumes secs (en raison du déficit de production de légumineuses dans le pays), et d) la production de grains d'arachide partiellement dégraissés pour le marché d'exportation.

1. Scientist, Oilseed Technology Area, Central Food Technological Research Institute (CFTRI), Mysore 570 013, India.

Multiple Uses of Groundnut

L.J. Reddy, S.N. Nigam, and R. Jambunathan[1]

The groundnut plant comprises approximately 10% roots, 45% vines and leaves, and 45% pods. The roots and nodules add 125–178 kg of nitrogen ha^{-1} to the soil through nitrogen fixation. The vines and leaves are used as green, dry, or silage fodder and as fertilizer or fuel. Groundnut husk constitutes about 13% of the whole plant and is put to several uses. The whole seed, which constitutes 32% of the total mass of the plant, is used for oil and food. The groundnut oil is mainly used for cooking, and in industry for the preparation of several domestic products. The protein-rich cake or meal after oil extraction is usually fed to livestock or used as fertilizer. However, in recent years, with proper processing, the meal is being utilized for making products such as hot cakes, biscuits, and baby or invalid foods. Whole seed, cotyledons, flakes, grits, and flour of groundnut are utilized in the preparation of various full-fat, partially defatted, and defatted products.

Several groundnut protein-fortified foods such as 'Pronutro' (South Africa, Malawi, Swaziland, Zimbabwe), 'Arlac' (Nigeria), 'Lady Lac' (Senegal), 'Amama' (Nigeria, Uganda, Kenya), 'Multipurpose Food', and 'Bal Ahar' (India), beverages such as 'Miltone' and 'Milpro', and biscuits ('Probisk' and 'Uniprotein') are being produced on a commercial scale. In Andhra Pradesh, India, groundnut is consumed as a main meal such as *Tapiluntalu* by the small farmers and various snacks made of groundnut such as *Pelapinidi Untalu* and *Polilu*, are also very popular.

Usages multiples de l'arachide

Le plant d'arachide comprend environ 10% de racines, 45% de tiges et de feuilles et 45% de gousses. Les racines et les nodules ajoutent 125–178 kg d'azote par hectare au sol à la fixation d'azote. Les tiges et les feuilles servent comme fourrage vert, sec ou en silo et comme engrais ou comme combustible. Les coques d'arachide constituent environ 13% du total du plant et servent à différents usages. La semence entière qui constitue 32% de la masse totale du plant sert à la production d'huile et de produits alimentaires. L'huile d'arachide sert surtout à la cuisine et à l'industrie pour la préparation de plusieurs produits domestiques. Le tourteau, riche en protéines, ou la farine après extraction d'huile sont surtout donnés au bétail ou jouent le rôle d'engrais. Toutefois, depuis quelques années, en raison de l'amélioration du traitement, la farine est davantage utilisée pour faire des produits tels que des gâteaux, des biscuits, des aliments pour jeunes enfants ou malades. Le grain entier, les cotylédons, flocons et farine d'arachide servent à la préparation de divers produits qui contiennent toutes les matières grasses, qui n'en contiennent qu'une partie ou qui sont entièrement dégraissés.

Plusieurs aliments fortifiés par la protéine d'arachide comme le "Pronutro" (Afrique du Sud, Malawi, Swazilande, Zimbabwe), et "Arlac" (Nigéria), "Lady Lac" (Sénégal), "Amama" (Nigéria, Ouganda, Kenya), "aliments multi-fins", et "Bal Ahar" (Inde), des boissons comme "Miltone" et "Milpro", des biscuits ("Probisk" et "Uniprotéine"), sont actuellement produits sur une base commerciale. Dans l'état d'Andhra Pradesh, en Inde, l'arachide est consommée comme plat principal de repas comme le *Tapiluntalu* par les petits cultivateurs et différents casse-croûte d'arachide, comme le *Pelipinidi Untalu* et le *Polilu*, qui sont également très populaires.

1. Senior and Principal Plant Breeders, and Principal Biochemist (Crop Quality), International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh 502 324, India.

Optimization of Tortilla Formulations Containing Wheat, Groundnut, and Cowpea Flours

S.D. Holt, A.V.A. Resurreccion, and K.H. McWatters[1]

Sensory and physical characteristics of tortillas containing composite blends of wheat (*Triticum aestivum*), groundnut, and cowpea (*Vigna unguiculata*) flours were evaluated by mixture response surface methodology. Optimum wheat flour substitution in formulations was determined. Results indicated that wheat flour can be successfully replaced with up to 46% defatted groundnut flour and 24% cowpea flour to yield tortillas with quality characteristics comparable to those containing 100% wheat flour. Sensory evaluation indicated that a beany flavor was the most limiting attribute in optimizing formulations containing groundnut and cowpea flours. Sensory attributes are significantly correlated with physical and compositional measures of tortillas and physical measures of tortilla dough.

Optimisation des formules de tortilla contenant des farines de blé, d'arachide et de niébé

Les caractéristiques sensorielles physiques des tortillas contenant des mélanges composés de farines de blé (*Triticum aestivum*), d'arachide et de niébé (*Vigna unguiculata*), ont été évaluées par la méthodologie de réponse aux mélanges. Le remplacement optimum de farines de blé dans des formules a été déterminé. Ces résultats indiquaient que la farine de blé peut être remplacée avec succès par jusqu'à 46% de farine d'arachide dégraissée et 24% de farine de niébé pour fournir des tortillas qui ont des caractéristiques de qualités comparables à celles qui ne contiennent que 100% de farine de blé. L'évaluation sensorielle a indiqué qu'une saveur ressemblant à celle du haricot était l'attribut limite le plus évident dans les formules optimales contenant des farines d'arachide et de niébé. Les attributs sensoriels présentent une corrélation significative avec les mesures physiques et de composition des tortillas et les mesures physiques de la pâte de tortilla.

1. Graduate Research Assistant, Associate Professor, and Assistant Professor, Food Safety and Quality Enhancement Laboratory, University of Georgia, Griffin, GA 30223–1797, USA.

Supported by the United States Agency for International Development, Peanut Collaborative Research Support Program and Bean/Cowpea Collaborative Research Support Program.

Catalase Production by *Aspergillus parasiticus* in Groundnut Milk

M.R.S. Clavero, Y.C. Hung, L.R. Beuchat, and T. Nakayama[1]

Changes in catalase content and pH of groundnut milk in which *Aspergillus parasiticus* was cultured at 30°C were monitored over a 10-day period. A 3 to 10-fold increase in catalase content was detected during the first 6 days of incubation while catalase added to noninoculated (control) groundnut milk decreased by about 15% within 3 days. The pH of noninoculated catalase-supplemented milk increased from 6.7 to 9.2 whereas growth of *A. parasiticus* maintained the pH within the 7–8 range during the 10–day incubation period. Production of catalase by aflatoxigenic aspergilli, and perhaps other molds, could serve as a basis for developing a method for separating infected and sound groundnut seeds on a commercial scale.

Production de catalase par *Aspergillus parasiticus* dans le lait d'arachide

Des changements de la teneur en catalase et du pH de lait d'arachide dans lesquels l'*Aspergillus parasiticus* a été cultivé à 30°C ont été surveillés pendant une période de 10 jours. Une augmentation au triple ou au décuple de la teneur en catalase a été dépistée pendant les six premiers jours de l'incubation, tandis que l'addition de catalase à du lait d'arachide non-inoculé (témoin) diminuait d'environ 15% en trois jours. Le pH de lait enrichi de catalase et non inoculé augmentait de 6,7 à 9,2 tandis que la croissance d'*A. parasiticus* maintenait le pH dans la gamme 7–8 pendant la période d'incubation de 10 jours. La production de catalase par les *Aspergillus* aflatoxigéniques et peut être d'autres moisissures peuvent servir de base pour développer une méthode de séparation des grains affectés et sains sur une base commerciale.

---

1. Graduate Research Assistant, Associate Professor, and Professors, Food Safety and Quality Enhancement Laboratory, University of Georgia, Griffin, GA 30223–1797, USA.

Supported by the United States Agency for International Development, Peanut Collaborative Research Support Program.

Physical and Sensory Properties of Foods Supplemented with Fermented Groundnut Milk

C. Lee and L.R. Beuchat[1]

The effect of substituting groundnut milk fermented with mixed cultures of *Lactobacillus delbrueckii* subsp *bulgaricus* and *Streptococcus salivarivus* subsp *thermophilus* for buttermilk on physical, chemical, and sensory properties of three commercial brands of salad dressing was investigated. Increased amounts of fermented groundnut milk in dressings, resulted in decreased lightness, oil emulsion capacity, viscosity, and creamy flavor. The extent of change was dependent upon the brand of dressing. Fermented groundnut milk can be substituted for buttermilk at levels up to 25% without causing significant reduction in sensory qualities of salad dressing.

Propriétés physiques et sensorielles d'aliments enrichis au moyen de lait fermenté d'arachide

L'effet de l'emploi de lait d'arachide fermenté par des cultures de *Lactobacillus delbrueckii*, sous-espèce de *bulgaricus* et *Streptococcus salivarivus*, sous espèce *thermophilus*, à la place de babeurre, sur les propriétés physiques, chimiques et sensorielles de trois marques commerciales d'assaisonnement de salade a été étudié. Des quantités accrues de lait d'arachide fermenté dans l'assaisonnement réduisaient la légèreté, la capacité à l'émulsion d'huile, la viscosité et le goût crémeux. La quantité de changement dépendait de la marque de produit. Le lait d'arachide fermenté peut remplacer le babeurre selon une proportion allant jusqu'à 25% sans provoquer de réduction significative des qualités sensorielles des produits d'assaisonnement de salade.

1. Graduate Research Assistant and Professor, Food Safety and Quality Enhancement Laboratory, University of Georgia, Griffin, GA 30223–1797, USA.

Supported by the United States Agency for International Development, Peanut Collaborative Research Support Program.

Development of Some New Groundnut Products in Thailand

V. Haruthaithanasan[1]

The Department of Product Development has collaborated with the Peanut CRSP, USA, to work on "appropriate technology for storage/utilization of peanut". The major objectives of the project are: 1) to improve the processing technology and quality of Thai traditional products, 2) to develop some new products and to test their consumer acceptance, 3) to utilize partially defatted groundnut flour and low fat groundnut flour mainly to replace meat and to increase protein content in some kinds of snack foods, and 4) to use undersize seeds for use by pet animals as in dog food.

Some of the major tasks in implementing the work are: 1) to contact the researchers with the food industries to run the pilot scale production, 2) to produce a product and send the sample to a catering house for using it as an ingredient in the preparation of the food such as tempeh, 3) to demonstrate how to use groundnut tempeh in the preparation of Thai foods, 4) to write a column in the newspaper to give publicity, and 5) to direct a small-scale food factory to implement the scheme.

Some of the future activities of the project include: 1) transfer of technology of some of the products to the private sector, 2) improvement and product development of groundnut product to meet the consumer requirement, especially on nutritional product development and consumer preference, and 3) checking the quality of newly developed groundnut from the breeders.

Développement de quelques nouveaux produits arachidiers en Thaïlande

Le département de développement des produits a collaboré avec Peanut CRSP, Etats-Unis, pour mettre au point une "technologie appropriée pour le stockage et l'utilisation de l'arachide". Les principaux objectifs du projet sont: 1) d'améliorer la technologie de traitement et la qualité de produits thaï traditionnels; 2) de développer quelques nouveaux produits et de tester leur acceptabilité par les consommateurs; 3) d'utiliser de la farine d'arachide partiellement dégraissée et de la farine à faible teneur en matière grasse, surtout pour remplacer la viande et pour accroître la teneur protéique de certains types de casse-croûte ou snacks et 4) d'utiliser des semences de faible dimension pour les animaux domestiques comme produits d'alimentation des chiens.

Certaines des tâches principales de ce travail consistent: 1) à entrer en contact avec des chercheurs des industries alimentaires pour entreprendre la production sur une échelle pilote; 2) élaborer un produit et envoyer l'échantillon à une firme de restauration pour l'utiliser comme ingrédient pour la préparation de produits tels que le tempeh; 3) démontrer comment se servir de tempeh d'arachide pour la préparation des produits thaïs; 4) rédiger une colonne dans un journal pour faire connaître le produit; 5) aiguiller une usine alimentaire sur petite échelle pour qu'elle applique ce projet.

Certaines des activités ultérieures de ce projet comportent: 1) transfert de technologie de certains des produits au secteur privé; 2) amélioration et développement des produits d'arachide pour répondre aux besoins des consommateurs, surtout en ce qui concerne le développement de produits nutritifs et la préférence des consommateurs et 3) vérifier la qualité de l'arachide récemment développée par les sélectionneurs.

1. Head, Department of Product Development, Faculty of Agro-Industry, Kasetsart University, 50 Paholyothin Road, Bangkok 10900, Thailand.

Development of *Tempeh*-like Product from Groundnut

S. Suwannakij, P. Chompreeda, and V. Haruthaithanasan[1]

Groundnut *tempeh* has high potential for use in vegetarian foods to replace some soybean (*Glycine max*) products that are now the main source of protein food in the vegetarian food system in Thailand. Partially defatted groundnut was inoculated with starter of *Rhizopus oligosporus* and incubated at room temperature for 20 h to prepare groundnut *tempeh*. Chemical composition, amino acids, and free fatty acids of dried groundnut *tempeh* were not different from that of the partially defatted groundnut. Riboflavin in *tempeh* product was higher than in the partially defatted groundnut. When sausage was supplemented with 30% dried groundnut *tempeh*, there was no difference in scores for color, flavor, texture, and the acceptability score of 7 (9 = highly acceptable).

Développement de produits de type *Tempeh* à partir d'arachide

Le *tempeh* d'arachide a un grand potentiel d'usage dans les aliments végétariens pour remplacer une partie des produits à base de soja (*Glycine max)* qui sont actuellement la source principale de protéines dans le système végétarien en Thaïlande. De l'arachide partiellement dégraissée a été inoculée au moyen d'inducteurs de *Rhizopus oligosporus* et incubée à température ambiante pendant 20 jours pour préparer du *tempeh* d'arachide. La composition chimique, les acides aminés et les acides gras libres de *tempeh* à arachide séchée ne différaient pas beaucoup de ceux de l'arachide partiellement dégraissée. La riboflavine du produit *tempeh* était plus élevée que dans l'arachide partiellement dégraissée. Lorsqu'une saucisse était enrichie au moyen de 30% de *tempeh* d'arachide sèche, il n'y avait pas beaucoup de différence de classement pour la couleur, la saveur, la texture et l'acceptabilité de 7 (9 = très acceptable).

1. Graduate Student, Principal Investigator (Peanut CRSP), and Head, Department of Product Development, Faculty of Agro-Industry, Kasetsart University, 50 Paholyothin Road, Bangkok 10900, Thailand.

Improvement of Process and Quality of Ground Roasted Groundnut

S. Pojjanapimol[1], V. Haruthaithanasan[2], P. Chompreeda[2], and C. Oupadissakoon[2]

Small-sized Tainan 9 groundnut free from aflatoxin and defects was used as the raw material in this study. Good quality groundnut was processed by roasting it at 150°C for 15 min and grinding by a two-roller machine with 1.6 mm clearance. Results indicated that the improved ground roasted nuts had better quality in terms of indicators of rancidity (peroxide value) and safety (filth, aflatoxin, and microbial counts) than the marketed product. Seventy-six percent of general public consumers indicated that they liked the product and preferred packaging in aluminum foil bags. Supermarkets were the preferred place for marketing the product. Small packs (15 g) should cost 1 Baht (US$ 0.04). Eighty-eight percent of consumers, however, accepted the product packed in polyethylene bags.

Amélioration du processus et de la qualité d'arachide torréfiée

Des arachides Tainan 9, de petites dimensions, exemptes d'aflatoxines et de défauts, ont servi de matière première à cette étude. Des arachides de bonne qualité étaient traitées en les grillant à 150°C pendant 15 minutes et en les broyant dans une machine à deux rouleaux avec un battement de 1.6 mm. Les résultats indiquaient que les grains grillés et moulus de cette manière avaient une meilleure qualité en ce qui concerne les indicateurs de rancidité (valeur de péroxyde) et sécurité (propreté, aflatoxine, et numération microbienne) que le produit vendu sur le marché. Soixante-six pour cent des consommateurs du grand public indiquaient qu'ils préféraient le conditionnement en film d'aluminium. Les supermarchés étaient le meilleur endroit pour commercialiser ce produit. De petits paquets (15 g), devraient coûter 1 Baht (0.04 US$). Quatre-vingt huit pour cent des consommateurs, toutefois, acceptaient le produit lorsqu'il était vendu dans des sacs de polyéthylène.

1. Senior Scientist, Food Analysis Division, Department of Medical Science, Ministry of Public Health, Bangkok 10100, Thailand.
2. Head, Department of Product Development, Principal Investigator (Peanut CRSP), and Assistant Professor, Department of Product Development, Faculty of Agro-Industry, Kasetsart University, 50 Paholyothin Road, Bangkok 10900, Thailand.

Appendices

Chairpersons and Rapporteurs

Groundnut Production and Trade

Chair	: J.C. Davies
Co-Chair	: T.G. Kelley
Rapporteurs	: P. Subrahmanyam and Piara Singh

Regional Reviews

Americas

Chair	: C.R. Escano
Co-Chair	: D.H. Smith
Rapporteurs	: V.K. Mehan and F. Waliyar

Africa

Chair	: B.K. Patel
Co-Chair	: D.V.R. Reddy
Rapporteurs	: S.B. Sharma and B.J. Ndunguru

Asia and Australasia

Chair	: R. Schilling
Co-Chair	: J.P. Moss
Rapporteurs	: R.C. Nageshwar Rao and J.H. Williams

Donor Reports

Chair	: N.B. Tounkara
Co-Chair	: B.C.G. Gunasekera and D. McDonald
Rapporteurs	: Fauzdar Singh and C.L.L. Gowda

Special Topics

Information Transfer

Chair	: J. Smartt
Co-Chair	: D.G. Faris
Rapporteurs	: E.M. McGaw and A.K. Singh

Processing and Products

Chair	: D.G. Cummins
Co-Chair	: R. Jambunathan
Rapporteurs	: N. Mallikarjuna and V.M. Ramraj

Insect Pest Management

Chair	: S.M. Misari
Co-Chair	: J.A. Wightman
Rapporteurs	: G.V. Ranga Rao and S.L. Dwivedi

Genetic Resources and Biotechnology

Chair	: R.W. Gibbons
Co-Chair	: J.P. Moss
Rapporteurs	: K.K. Sharma and H.D. Upadhyaya

Crop Modeling

Chair	: G.F. Arkin
Co-Chair	: S.M. Virmani
Rapporteur	: Piara Singh

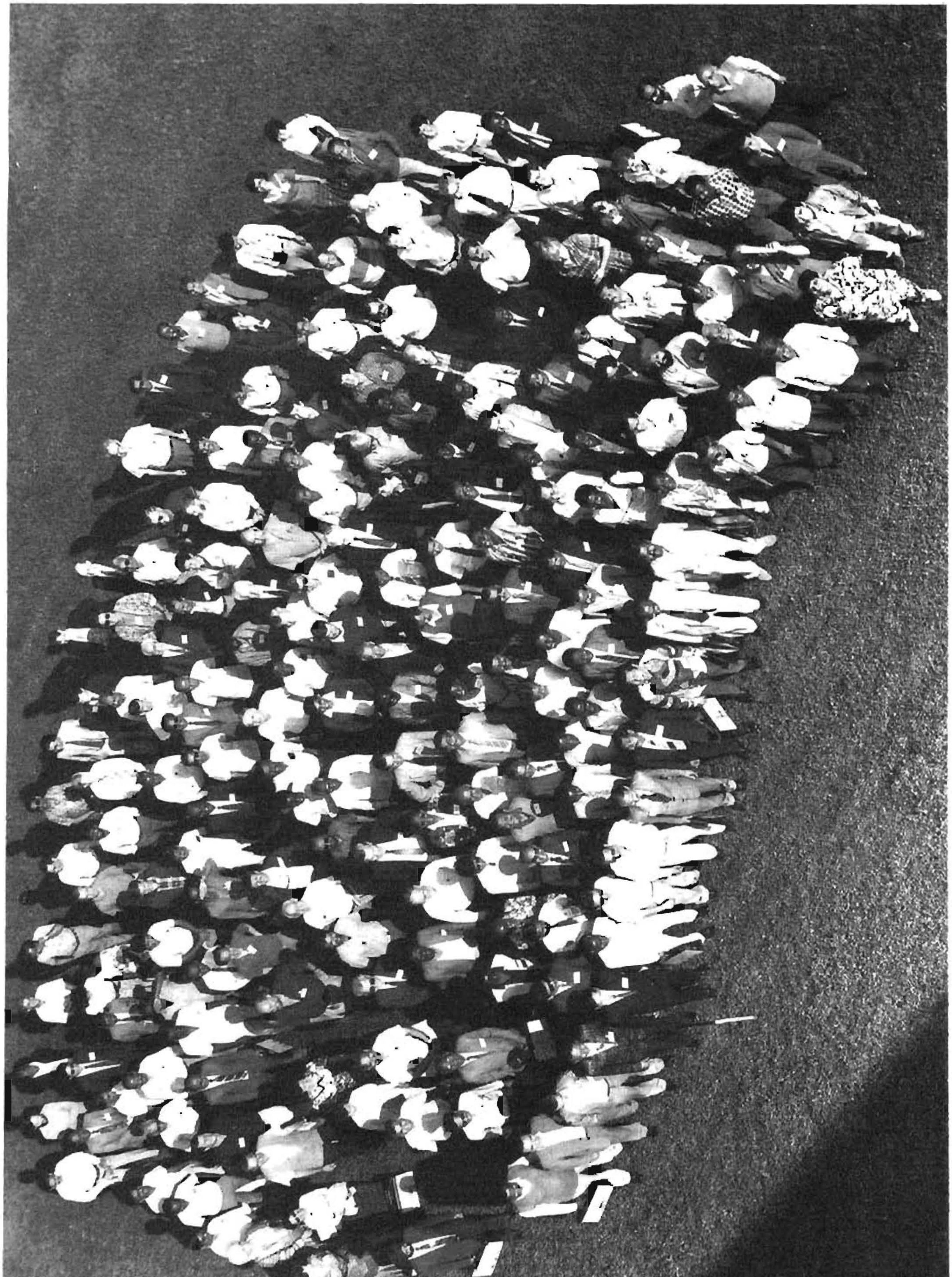
Network

Chair	: A. Ba
Co-Chair	: G. Schmidt
Rapporteurs	: O. Ito and D.S. Bisht

Seed Quality

Chair	: N.B. Tounkara
Co-Chair	: B.C.G. Gunasekera and D. McDonald
Rapporteurs	: Fauzdar Singh and C.L.L. Gowda

Participants



Workshop Participants, 28 Nov 1991, ICRISAT Center

Participants

ANTIGUA AND BARBUDA

B.R. Cooper
Caribbean Agricultural Research and
Development Institute (CARDI)
P.O. Box 766
Friars Hill
St. John's

ARGENTINA

E.H. Giandana
Estacion Experimental Agropecuaria
del INTA
5988 – Manfredi
Córdoba

AUSTRALIA

A.W. Cruickshank
Queensland Department of Primary
Industries
J. Bjelke-Petersen Research Station
P.O. Box 23
Kingaroy
Queensland 4610

K.J. Middleton (deceased)
Plant Pathology Branch
Queensland Department of Primary
Industries
J. Bjelke-Petersen Research Station
P.O. Box 23
Kingaroy
Queensland 4610

G.C. Wright
Queensland Department of Primary
Industries
J. Bjelke-Petersen Research Station
P.O. Box 23
Kingaroy
Queensland 4610

BANGLADESH

H.R.I. Avery
Crop Diversification Programme
Khamarbari
Middle Building
6th Floor
Farmgate
Dhaka 1215

M.S. Hoque
Oilseed Research Centre
Bangladesh Agricultural Research Institute
Joydebpur
Gazipur

M.S. Islam
Pulse and Oilseed Project
Bangladesh Agricultural Development
Corporation
49-51 Dilkusha Command Area
Matijheel
Dhaka

R.I. Mondal
Oilseed Research Centre
Bangladesh Agricultural Research
Institute
Joydebpur
Gazipur

S.A. Moqjit
Bangladesh Agricultural Development
Corporation
49-51 Dilkusha Command Area
Matijheel
Dhaka

BOTSWANA

A. Mayeux
Oilseed Division
Department of Agricultural Research
Sebele Research Station
Private Bag 0033
Gaborone

BRAZIL

I.J. Godoy
Instituto Agronomico
C.P. 28
13001 – Campinas
São Paulo

BURKINA FASO

S. Philippe
University of Ouagadougou
B.P. 7021
Ouagadougou

B. Saidou
Station de recherches agricoles
B.P. 32
Niangoloko

T. Seydou
Institut national d'etudes et de
recherches agricoles (INERA)/SARIA
B.P. 10
Koudougou

CAMEROON

E.B. Nehru
Institut de la recherche agronomique (IRA)
Centre IRA de Nkolbisson
P.O. Box 2067
Yaounde

CIS (formerly USSR)

I. Elizaveta
Central Asian Branch of All Union Research
Institute of Plant Industry
POS Botanika
Tashkent 702134

FRANCE

R. Schilling
Institute de recherches pour les
huiles et oléagineux (IRHO)
Centre de coopération internationale
en recherche agronomique pour
le développement (CIRAD)
B.P. 5035
34032 Montpelliar cedex 01

GAMBIA

S. Drammeh
Department of Agricultural Research
Yundum Research Station
Western Division
Yundum

GHANA

K.O. Marfo
Food Legumes Section
Nyankpala Agricultural Experiment
Station
P.O. Box 52
Nyankpala
Tamale

GUINEA

N.B. Tounkara
Centre de recherche agronomique
de foulaya
B.P. 156
Kindia

INDIA

K.S. Amin
National Research Centre for
Groundnut (NRCG)/ICAR
Ivnagar Road
P.O. Timbawadi 362 015
Dist. Junagadh
Gujarat

P.W. Amin
Punjabrao Krishi Vidyapeeth
Krishinagar
Akola 444 104
Maharashtra

L. Ananda Reddy
Centre for Plant Molecular Biology
Department of Genetics
Osmania University
Hyderabad 500 007
Andhra Pradesh

A. Bandyopadhyay
National Research Centre for
Groundnut (NRCG)/ICAR
Ivnagar Road
P.O. Timbawadi 362 015
Dist. Junagadh
Gujarat

M.S. Basu
National Research Centre for
Groundnut (NRCG)/ICAR
Ivnagar Road
P.O. Timbawadi 362 015
Dist. Junagadh
Gujarat

N.R. Bhagat
National Research Centre for
Groundnut (NRCG)/ICAR
Ivnagar Road
P.O. Timbawadi 362 015
Dist. Junagadh
Gujarat

S. Desai
National Research Centre for
Groundnut (NRCG)/ICAR
Ivnagar Road
P.O. Timbawadi 362 015
Dist. Junagadh
Gujarat

M.P. Ghewande
National Research Centre for
Groundnut (NRCG)/ICAR
Ivnagar Road
P.O. Timbawadi 362 015
Dist. Junagadh
Gujarat

S.A. Ghorpade
Agriculture Research Station
Mahatma Phule Agricultural University
Jalgaon 425 001
Maharashtra

K. Giri Raj
Main Research Station
University of Agricultural Sciences
Dharwad 580 005
Karnataka

S.C. Gupta
Harrisons Malayalam Limited
Centenary Building
3rd Floor
28 M.G. Road
Bangalore 560 001
Karnataka

K.P. Hatkar
Agricultural Research Station
Mahatma Phule Agricultural University
Jalgaon 425 001
Maharashtra

P.K. Joshi
National Research Centre for
Groundnut (NRCG)/ICAR
Ivnagar Road
P.O. Timbawadi 362 015
Dist. Junagadh
Gujarat

Y.C. Joshi
National Research Centre for
Groundnut (NRCG)/ICAR
Ivnagar Road
P.O. Timbawadi 362 015
Dist. Junagadh
Gujarat

J.B. Misra
National Research Centre for
Groundnut (NRCG)/ICAR
Ivnagar Road
P.O. Timbawadi 362 015
Dist. Junagadh
Gujarat

P. Narasimha Reddy
Agricultural Research Station
Andhra Pradesh Agricultural
University
Kadiri
Anantapur District
Andhra Pradesh

M.V. Nayudu
Virology Department
Sri Venkateswara University
Tirupati 517 502
Andhra Pradesh

V.J. Patel
Oilseed Research Station
Gujarat Agricultural University
Junagadh 362 001
Gujarat

S.A. Patil
Regional Research Station
University of Agricultural Sciences
P.B. No. 24
Raichur 584 101
Karnataka

M.V.R. Prasad
Directorate of Oilseeds Research
Rajendranagar
Hyderabad 500 030
Andhra Pradesh

T.G. Prasad
Department of Crop Physiology
University of Agricultural Sciences
GKVK Campus
Bangalore 560 065
Karnataka

Y.C. Prasad
Agricultural Research Station
Durgapura
Jaipur 302 018
Rajasthan

L. Ram Dev Reddy
Centre for Plant Molecular Biology
Department of Genetics
Osmania University
Hyderabad 500 007
Andhra Pradesh

V. Ranga Rao
Directorate of Oilseeds Research
Rajendranagar
Hyderabad 500 030
Andhra Pradesh

A.R. Reddy
School of Life Sciences
University of Hyderabad
P.O. Central University Campus
Gachibouli
Hyderabad 500 134
Andhra Pradesh

D.D.R. Reddy
Department of Entomology
College of Agriculture
Andhra Pradesh Agricultural University
Rajendranagar
Hyderabad 500 030
Andhra Pradesh

G.Y. Reddy
National Dairy Development Board
1 Floor, Ceebros Centre
45 Monteith Road
Egmore
Madras 600 008
Tamil Nadu

P.S. Reddy
National Research Centre for Groundnut (NRCG)/ICAR
Ivnagar Road
P.O. Timbawadi 362 015
Dist. Junagadh
Gujarat

N.K. Sanghi
Central Research Institute for Dryland Agriculture (CRIDA)
Santoshnagar
Hyderabad 500 030
Andhra Pradesh

V.R. Sashidhar
Department of Crop Physiology
University of Agricultural Sciences
GKVK Campus
Bangalore 560 065
Karnataka

M.C.S. Sastry
Oilseeds Technology Area
Central Food Technological Research Institute
Mysore 570 103
Karnataka

V.K. Sathiyanandam
Regional Research Station
Tamil Nadu Agricultural University
Vriddhachalam 606 001
Tamil Nadu

P. Sen
National Research Centre for
Groundnut (NRCG)/ICAR
Ivnagar Road
P.O. Timbawadi 362 015
Dist. Junagadh
Gujarat

D. Sharma
56, ICRISAT Colony
Tarband
Secunderabad
Andhra Pradesh

A.B. Singh
Groundnut Research Station
Mainpuri 205 001
Uttar Pradesh

B.S. Singh
National Dairy Development Board
Anand 388 001
Gujarat

H. Singh
Department of Plant Breeding
Haryana Agricultural University
Hisar 125 004
Haryana

S. Thangavelu
Regional Research Station
Tamil Nadu Agricultural University
Vriddhachalam 606 101
Tamil Nadu

K.M. Usman
Regional Research Station
Tamil Nadu Agricultural University
Vriddhachalam 606 001
Tamil Nadu

K.S. Varaprasad
Plant Quarantine Regional Station
National Bureau of Plant Genetic
Resources (NBPGR)
ARI Campus
Rajendranagar
Hyderabad 500 030
Andhra Pradesh

S. Vijayakumar
Regional Research Station
University of Agricultural Sciences
P.B. No. 24
Raichur 584 101
Karnataka

M.D. Wasnik
Directorate of Oilseeds Development
Himayatnagar
Hyderabad 500 029
Andhra Pradesh

C.P.S. Yadava
AICR Project on Whitegrub Research
Agricultural Research Station
Indian Council of Agricultural
Research (ICAR)
Durgapura
Jaipur 302 015
Rajasthan

INDONESIA

D.M. Arsyad
Central Research Institute for Food
Crops-BORIF
Jalan Merdeka 147
Bogor 10002

Djamaluddin
Maros Research Institute for Food
Crops (MORIF)
P.O. Box 173
(Balittan Maros)
MAROS
South Sulawesi

A. Kasno
Malang Research Institute for Food
Crops (MARIF)
Jln. Raya Kendalpayak
P.O. Box 66
Malang 65101
East Java

N. Saleh
Malang Research Institute for Food
Crops (MARIF)
Jln. Raya Kendalpayak
P.O. Box 66
Malang 65101
East Java

B.S. Soekarno
Malang Research Institute for Food Crops (MARIF)
Jln. Raya Kendalpayak
P.O. Box 66
Malang 65101
East Java

I.M. Tantera
Food and Agriculture Organization of the United Nations (FAO)
RAS/89/040
Jalan Merkeka 145
Bogor 16111

ITALY

V. Ramanatha Rao
International Board for Plant Genetic Resources (IBPGR)
c/o Food and Agricultural Organization of the United Nations (FAO)
via delle Sette Chiese 142
00145 Rome

JAMAICA

U. Wilson
Caribbean Agricultural Research and Development Institute (CARDI)
University of the West Indies
Mona Campus
P.O. Box 113
Kingston

JAPAN

H. Gocho
Ecophysiology Research Division
Tropical Agriculture Research Center (TARC)
Ministry of Agriculture, Forestry and Fisheries
1-2, Ohwashi
Tsukuba
Ibaraki, 305

K. Maeda
Lab of Crop Science
The Faculty Farm
Faculty of Agriculture
Kochi University
Monobe Nankoku
Khochi 783

KENYA

F.H. Kiriro
Regional Research Centre
Kenya Agricultural Research Institute (KARI)
P.O. Box 169
Kakamega

M.M. Siambi
Kenya Agricultural Research Institute (KARI)
National Dryland Farming Research Centre
P.O. Box 340
Machakos

MALAWI

C.A. Phangaphanga (deceased)
Ministry of Agriculture
Chitedze Agricultural Research Station
P.O. Box 158
Lilongwe

MALAYSIA

S.Z. Ramawas
Malaysian Agricultural Research and Development Institute (MARDI)
Ketua Stesen
Stesen Penyelidikan Hortikultur
MARDI Station at Gajah Mati
06400 Pokok Sena
Kedah Darulaman

MALI

S. Traore
Institut d'economie rural (IER)
DRA/SRCVO
Sotuba
B.P. 438
Bamako

MOZAMBIQUE

M.J. Freire
Department of Crop Protection and Production
Faculty of Agronomy
Universidade Eduardo Mondlane
C.P. 257
Maputo

MYANMAR

Khin Nyo
Magwe Central Farm
Myanmar Agricultural Service
Magwe

Tin Soe
Central Agricultural Research Institute (CARI)
Myanmar Agricultural Service
Yezin
Pyinmana

Hla Than
Central Agricultural Research Institute (CARI)
Myanmar Agricultural Service
Yezin
Pyinmana

NAMIBIA

D.J.M. Marais
Department of Agriculture and Rural Development
Ministry of Agriculture, Fisheries, Water and Rural Development
P.O. Box 788
Grootfontein 9000

NEPAL

D.S. Pathic
Agricultural Research Station
National Rice Research Program
Parwanipur
Bara

G.B. Pradhan
Nepal Vegetable Ghee Industries Limited
P.B. No. 483
Kalimati
Kathmandu

NIGER

I. Oumarou
Institut national de recherches agronomiques du Niger (INRAN)
B.P. 429
Niamey

NIGERIA

A.A. Adesiyun
Department of Crop Production
University of Ilorin
Ilorin

S.M. Misari
Institute for Agricultural Research
Ahmadu Bello University
P.M.B. 1044
Samaru
Zaria

P.E. Olorunju
Institute for Agricultural Research
Ahmadu Bello University
P.M.B. 1044
Samaru
Zaria

PAKISTAN

Naazar Ali
Barani Agricultural Research and Development (BARD)
National Agricultural Research Centre
P.O. NARC
Islamabad

PEOPLE'S REPUBLIC OF CHINA

Huang Bingchao
Department of Entomology
Plant Protection Research Institute
Guangdong Academy of Agricultural Sciences
Wushan, Guangzhou 510640
Guangdong Province

Li Jianping
Department of Agronomy
Scientific Management Department
Chinese Academy of Agricultural Sciences
30 Bai Shi Qiao Road
Beijing 100081

Xu Zeyong
Department of Plant Protection
Oil Crops Research Institute
Chinese Academy of Agricultural Sciences
Wuhan 430062
Hubei

Yu Shanlin
Peanut Research Institute of Shandong
Laixi City
Shandong Province 266601

PHILIPPINES

R.M. Abilay
Institute of Plant Breeding
College of Agriculture
University of the Philippines at Los Baños
College
Laguna 4031

L.V. Buendia
Crop Research Division
Philippines Council for Agriculture, Forestry and Natural Resources Research and Development (PCARRD)
Los Baños
Laguna 4031

C.R. Escano
Crop Research Division
Philippines Council for Agriculture,
llege of Agriculture
University of the Philippines at Los Baños
College
Laguna 4031

V.R. Ocampo
Department of Entomology
College of Agriculture
University of the Philippines at Los Baños
College
Laguna 4031

SENEGAL

A. Ba
Institut sénégalais de recherche agricole (ISRA)
Secteur Centre Sud
B.P. 199
Kaolack

O. Ndoye
Institut sénégalais de recherche agricole (ISRA)
Secteur Centre Sud
B.P. 17
Nioro-du-Rip

SRI LANKA

R.H. Rajapakse
Faculty of Agriculture
University of Ruhuna
Mapalana
Kamburupitiya

B. Regunathan
Regional Agricultural Research Centre
Makandura
Gonawila, N.W.P.

L.C. Wijetilaka
Regional Agriculture Research Station
Maha Illuppallama

SUDAN

I.A.A. El-Dukheri
Oilseed Crops Development Project
Arab Organization for Agricultural Development (AOAD)
United Nations Development Programme (UNDP)
P.O. Box 429
El-Obeid

M.A. Mahmoud
Oilseed Crops Development Project
Arab Organization for Agricultural Development (AOAD)
United Nations Development Programme (UNDP)
P.O. Box 474
Khartoum

SWAZILAND

Z.I. Mamba
Malkerns Agricultural Research Station
P.O. Box 4
Malkerns

Y.P. Rao
Department of Crop Production
Faculty of Agriculture
University of Swaziland
P.O. Luyengo

TANZANIA

E.M. Kafiriti
Naliendele Research Institute
P.O. Box 509
Mtwara

F.F. Mwenda
Naliendele Research Institute
P.O. Box 509
Mtwara

K.P. Sibuga
Department of Crop Science and Production
Sokoine University of Agriculture
P.O. Box 3005
Morogoro

THAILAND

N. Chomchalow
Food and Agriculture Organization of the United Nations (FAO)
Regional Office for Asia and the Pacific
Maliwan Mansion
Phra Atit Road
Bangkok 10200

V. Haruthaithanasan
Faculty of Agro-Industry
Department of Product Development
Kasetsart University
Bangkok 10900

S. Jogloy
Department of Agronomy
Faculty of Agriculture
Khon Kaen University
Khon Kaen 40002

A. Patanothai
Groundnut Improvement Project
Khon Kaen University
Khon Kaen 40002

S. Wongkaew
Department of Plant Pathology
Faculty of Agriculture
Khon Kaen University
Khon Kaen 40002

UGANDA

P.B. Ateni
Namulonge Research Station
P.O. Box 7084
Kampala

UK

M.A. Bellamy
Division of Natural Resources, Forestry, and Economics
CAB International
Wallingford
Oxon OX10 8DE

J.C. Davies
Overseas Development Administration
94 Victoria Street
London SW1E 5SJ

J. Smartt
Department of Biology
School of Biological Science
Biometrical Sciences Building
University of Southampton
Bassett Crescent East
Hants S09 5NH

USA

G.F. Arkin
Georgia Experiment Station
University of Georgia
Griffin
GA 30223-1797

O. Badiane
International Food Policy Research
Institute (IFPRI)
1776 Massachusetts Avenue, N.W.
Washington
D.C. 20036-1998

L.R. Beuchat
Department of Food Science
Georgia Experiment Station
University of Georgia
Griffin
GA 30223-1797

K.J. Boote
Department of Agronomy
Institute of Food and Agricultural
Sciences
University of Florida
Gainesville
FL 32611-0311

L.J. Boyd
Department of International
Agriculture
201 Conner Hall
University of Georgia
Athens
GA 30602

G.S. Brar
Agracetus, Inc.
8520 University Green
Middleton
WI 53562

M. Chinnan
Department of Food Science and
Technology
Georgia Experiment Station
University of Georgia
Griffin
GA 30223-1797

D.G. Cummins
Peanut Collaborative Research
Support Program
Georgia Experiment Station
University of Georgia
528 Ivy Road
Griffin
GA 30223-1797

J.W. Demski
Department of Plant Pathology
Georgia Experiment Station
University of Georgia
Griffin
GA 30223-1797

S.M. Fletcher
Department of Agricultural
Economics
Georgia Experiment Station
University of Georgia
Griffin
GA 30223-1797

D.W. Gorbet
Department of Agronomy
Institute of Food and Agricultural
Sciences
University of Florida
North Florida Research and
Education Center, Marianna
3925 Highway 71
Marianna
FL 32446

J.F. Hennen
Department of Botany and Plant
Pathology
Purdue University
Lilly Hall of Life Sciences
West Lafayette
IN 47907

T.G. Isleib
Department of Crop Science
North Carolina State University
P.O. Box 7629
Raleigh
NC 27695-7629

J.W. Jones
Agricultural Engineering Department
Institute of Food and Agricultural Sciences
University of Florida
Gainesville
FL 32611

R.E. Lynch
Insect Biology and Population Management Research Laboratory
P.O. Box 748
Tifton
GA 31793-0748

T.D. Phillips
Department of Veterinary Public Health
Texas Agricultural and Mechanical University
College Station
TX 77843

F.M. Shokes
Department of Plant Pathology
Institute of Food and Agricultural Sciences
University of Florida
Route 3, Box 4370
Quincy
FL 32351-9529

B. Singh (deceased)
Peanut Collaborative Research Support Program
Department of Food Science and Animal Industries
Alabama Agricultural and Mechanical University
P.O. Box 264
Normal
AL 35762

H.T. Stalker
Department of Crop Science
North Carolina State University
P.O. Box 7629
Raleigh
NC 27695-7629

A.K. Weissinger
Department of Crop Science
North Carolina State University
P.O. Box 7620
Raleigh
NC 27695-7620

VIETNAM

N.D. Khoa
Institute for Agricultural Science in South Vietnam
121 Nguyen Binh Khiem Street
Ho Chi Minh City
T.V. Lai
Grain Legume Research and Development Center
National Institute of Agricultural Sciences (INSA)
Hanoi

N.H. Quang
Provincial Agricultural Department
Nghe An Province

L.M. Thi
Plant Pathology Section
Plant Protection Research Institute
Chem-Tuliem
Hanoi

YEMEN

Y.A. Ali
El-Kod Agricultural Research Centre
P.O. Box 309
El-Kod
Abyan
Aden

A.L.M. Saeed
Food Legumes Improvement Programme
Agricultural Research Authority and Extension
P.O. Box 31118
Amran

ZAMBIA

J.C. Musanya
Msekera Regional Research Station
P.O. Box 510089
Chipata

B.M. Syamasonta
Msekera Regional Research Station
P.O. Box 510089
Chipata

ZIMBABWE

Z.A. Chiteka
Crop Breeding Institute
Department of Research and
Socialist Services
P.O. Box 8100
Causeway
Harare

ICRISAT
Patancheru P.O.
Andhra Pradesh 502 324
India

M.M. Anders
D.S. Bisht
D.R. Butler
S.L. Dwivedi
D.G. Faris
A.M. Ghanekar
C.L.L. Gowda
L.J. Haravu
O. Ito
R. Jambunathan
C. Johansen
J.S. Kanwar
T.G. Kelley
K.R. Krishna
J.V.D.K. Kumar Rao
K.B. Laryea
D. McDonald
V.K. Mehan
M.H. Mengesha
J.P. Moss
R.C. Nageswara Rao
Nalini Mallikarjuna
Y.L. Nene
S.N. Nigam
D.L. Oswalt
B.K. Patel
C.S. Pawar
M.V. Potdar
A. Ramakrishna
V.M. Ramraj
G.V. Ranga Rao
L.J. Reddy
D.V.R. Reddy
O.P. Rupela
J.G. Ryan
Savithri Mohapatra
K.K. Sharma
S.B. Sharma
P.V. Shenoi
A.K. Singh
Faujdar Singh
Piara Singh
D.H. Smith
Suresh Pande
H.D. Upadhyaya
S. Vijay Ramchander
S.M. Virmani
B.J. Walby
J.A. Wightman

ICRISAT Sahelian Center
B.P. 12404
Niamey (via Paris)
Niger

R.W. Gibbons
B.J. Ndunguru
B.R. Ntare
F. Waliyar
J.H. Williams

SADCC/ICRISAT Groundnut Project
Chitedze Agricultural Research
Station
P.O. Box 1096
Lilongwe
Malawi

G.L. Hildebrand
G. Schmidt
P. Subrahmanyam

Acknowledgments

Organizing Committee

S.N. Nigam
D. McDonald
D.G. Faris
J.A. Wightman
D.H. Smith
E.M. McGaw
K. Sampath Kumar
P.R. Murthy
S.V. Ramana Rao

ICRISAT
International Crops Research Institute for the Semi-Arid Tropics
Patancheru, Andhra Pradesh 502 324, India

ISBN 92-9066-239-5

Order code: CPE 081

92-159