Strengthening conservation and utilization of ground-nut (*Arachis hypogaea* L.) genetic resources in West Africa

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Introduction

Plant genetic resources are the most valuable and essential basic raw material in meeting the current and future needs of crop improvement programmes to satisfy the demands of an increasing human population. The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) holds over 15 000 germplasm accessions of ground-nut at its Patancheru, India, gene bank. It has been a major source of diversity for ground-nut improvement worldwide. The gene bank distributes over 500 samples upon request every year. While 40% of this total is distributed within India, only a mall proportion is distributed in sub-Saharan Africa.

West Africa produces about 15% of the world ground-nut output and 60% of sub-Saharan Africa ground-nut production (Ndjeunga et al. 2003). The yields obtained are less than half of those obtained in India and China, and a quarter of those obtained in USA. Therefore, there is significant scope to improve the productivity and production of ground-nut in the region, for which the availability of adequate quantities of planting material is a basic necessity.

Exploitation of germplasm by regional and national organizations in West Africa was constrained by limited access to the diversity of the crop. The movement of genetic materials from one country to the other was very rare and subject to quarantine procedures to prevent the transmission of seed-borne diseases. This also applied to transfer of material available in the world ground-nut germplasm collection held by ICRISAT in India, and materials available in national agricultural research systems (NARS).

With the coming into force of the Convention on Biological Diversity (CBD), more and more countries are enacting laws for conservation and exchange of their genetic resources. Unless a multilateral system is evolved, these policies may hinder the free movement of germplasm from International Agricultural Research Centre gene banks, which hold the germplasm in trust for the benefit of the world community. At the same time, it is anticipated that demand for repatriation of germplasm from countries of origin would increase with the growing realization of the need for conserving biological diversity, and due to the fear that repatriation will be difficult in future. Regional working collections would provide ready access to a greater range of diversity for crop improvement scientists. In addition, such local working collections will provide opportunities to conduct in-country, regional multilocation evaluations to identify elite germplasm for direct release, or to conduct further improvement to remove constraints and sustain productivity. ICRISAT responded to this need by establishing a regional gene bank for assembly, characterization, evaluation, maintenance, conservation, documentation and distribution of ground-nut germplasm.

In 1996, ICRISAT in partnership with the Centre de cooperation international en recherché agronomique pour le development (CIRAD), France, and the Institut Senegalais de Recherché Agricole (ISRA), Senegal, initiated a regional ground-nut germplasm project. The Common Fund for Commodities (CFC) provided the financial support. The first task was to restore the genetic diversity of ground-nut in the region, and distribute seed of the best lines to research and development partners to contribute to the improvement of ground-nut productivity and the sustainability of ground-nut production systems in the subregion.

This paper describes the current status of ground-nut genetic resources conservation and utilization in West Africa.

Germplasm assembly, maintenance and conservation

Assembly

The initial plan was to duplicate all accessions (about 16 000) of the global germplasm collection at ICRISAT, Patancheru, India, to the ICRISAT Sahelian Centre, Niger. Following critical review, it was not found feasible to duplicate such a large number. To ensure that sufficient variability is maintained, a smaller working collection was assembled, containing 6000 accessions from 73 countries. Accessions originally assembled from West African countries are presented in **Table 1**, and those from other countries are presented in **Table 2**.

Table 1. Number of accessions collected or assembled from West African countries and conserved at the regional gene bank, ICRISAT-Niamey.

Country	Collected	Assembled	Total
Benin	0	11	11
Burkina Faso	0	26	26
Cameroon	25	0	25
Chad	41	44	85
Côte d'Ivoire	0	59	59
The Gambia	0	14	14
Ghana	29	9	48
Guinea	146	10	156
Guinea Bissau	0	59	59
Liberia	0	8	8
Mali	168	13	181
Niger	0	42	42
Nigeria	80	161	241
Senegal	0	185	185
Sierra Leone	2	15	17
Togo	11	20	31
Total	502	676	1169

Table 2. Number of designated accessions from other countries in the regional gene bank.

Origin	Accessions	Country	Accessions
Africa			
Angola	5	Rwanda	1
the Central African Republic	2	Swaziland	7
Egypt	5	Tanzania	329
Kenya	43	Uganda	133
Morocco	10	South Africa	26
Madagascar	38	Democratic Republic of the Congo	98
Mozambique	120	Zambia	118
Mauritius	3	Zimbabwe	612
Asia			
China	37	Malaysia	26
India	715	Philippines	13
Israel	9	Russia	5
Republic of Korea	37	Thailand	1
Myanmar	3	Taiwan	12
Malaysia	26	Viet Nam	2
the Philippines	13	Indonesia	39
Japan	15	Sri Lanka	5

the Americas			
Argentina	159	Paraguay	42
Bolivia	73	Suriname	1
Brazil	232	Uruguay	17
Barbados	4	United States of America	318
Costa Rica	1	Venezuela	4
Honduras	3	Ecuador	4
Jamaica	1	Cuba	7
Mexico	5		5
Peru	149		
Other			
Australia	9	Martinique	1
Cyprus	1	Unknown	153
Spain	2		
Total	3 693		

Maintenance and conservation

Germplasm conservation requires cleaning the seed materials, drying to minimal seed moisture content (3–4%), storing in cool and dry conditions, and monitoring seed health during storage (Kameswara Rao and Bramel 2000). The seed store at ICRISAT-Niamey was modified into a short- and medium-term store according to the International Gene Bank Standards specified by FAO and the International Plant Genetic Resources Institute (IPGRI). The short-term storage room is 9.1 m × 5.1 m × 2.45 m (ca. 113 m^3) in size and maintained at 15 ±2°C and 15 ±2% relative humidity (RH). Maximum seed viability and longevity are maintained under these storage conditions, which have been described as the best for orthodox seeds maintained at 5 ±2% seed moisture content. The room is also used for drying and processing of seeds before transfer to the medium-term store. It is also used for short-term storage of working collections and seed of popular varieties. The working collections are held in plastic containers holding about 2 kg.

The medium-term storage room is 5.4 m × 5.1 m × 2.45 m (ca 67 m^3), and maintained at 4 ±2°C and 30 ±5% RH. It holds the base collection of ground-nut, sealed in laminated aluminium foil containers. Orthodox seeds can be conserved for up to 15–25 years under these conditions without much loss in seed viability or vigour. About 60 seeds are stored per accession.

Static shelves are installed in both rooms. The storage environment is monitored through electronic loggers and a localized electronic alarm alerts staff in the event of any rise in temperature due to equipment failure. The power supply is from the national grid, with an independent back-up generator to cope with longer periods of power failure. With support from the World Bank, an additional room to accommodate 13 deep freezers has been constructed.

A seed laboratory of 6.0 m × 5.0 m × 3 m is available, with adequate infrastructure. It is equipped to monitor seed viability through germination tests in an incubator maintained at 25 ±5°C. Seed moisture content is determined by the oven method (100–250°C). There is also simple equipment for seed health monitoring. An air-cooled glasshouse is available to grow and multiply germplasm accessions with very few seeds.

Operational procedures

Maintenance of germplasm requires monitoring of seed viability and quantity in storage. When seed quantities fall below 50 g per accession or viability becomes less than 85%, the accessions must be rejuvenated in the field. This requires strict adherence to standards to minimize potential loss of genetic integrity and danger from the environment due to stresses. All the assembled germplasm has been rejuvenated, the seed processed, and stored in the medium-term store as a base collection. A protocol is in place that meets international standards recommended for rejuvenation, processing of seed, minimum viability and longevity, seed quantities and maintenance of seed health. This is to ensure production of good quality seed for distribution, and also to help avoid genetic shift that might occur as a result of selection pressure imposed during crop growth.

The management of information on the accessions required the development of linkage among basic types of data, including passport, characterization, evaluation, inventory, regeneration, processing and distribution of accessions. This constitutes a gene bank management system, and allows continuous access to information on the status of the collection, and ensures security, which is critical to the wider use of the germplasm. The procedures and processes have been compiled in a manual that outlines the aspects of gene bank management and conservation (Kameswara Rao and Bramel 2000; Mayeux and Ntare 2001b). This has been widely distributed.

Germplasm documentation

From the moment an accession is collected or acquired, it is documented in great detail. This information includes precise origin and evolution, the botanical classification, characteristics, past evaluation and value, rejuvenation history, seed viability, placement in the various types of storage and past distribution. The collection and maintenance of this information is a key component of the conservation of *ex situ* collections. The availability of all or part of this information is fundamental to the effective and efficient use of the accessions. The assembled germplasm has been documented in various forms, including as printed catalogues, digitally on CD-ROM, and posted on the Web (**www.icrisat.org**).

Diversity of the assembled germplasm

The collection consists of accessions originating from 73 countries, but the majority is from India (14%), Zimbabwe (12%), United States of America (6%), Tanzania (6%) and Brazil (5%). In West Africa, Nigeria (5%), Senegal (4%) Mali (4%), Guinea (3%) and Chad (2%) constitute the main sources.

Botanical types fall into five major groups: Hypogaea bunch (30%), Hypogaea runner (16%), Vulgaris (36%), Fastigiata (15%) and Peruvian (4%). Only 8 accessions represent Hirsuta and only 1 represents Aequatoriana. Of the accessions, 45% exhibit an erect plant growth habit, while the spreading, spreading/bunch and bunch categories comprise less than 25% of the accessions. Most (53%) are breeding lines, and the remaining 47% are landraces.

There are four major maturity groups, namely extra-early (80–90 days), early (90–115 days), medium (115–120 days) and late maturity (>120 days). Variability is also wide in terms of oil content, edible ground-nut traits and fodder production.

Characterization and evaluation of germplasm

Characterization for botanic characteristics

Agronomic and botanical characterization of germplasm is necessary to enhance its utility for greater use by the research workers. The germplasm has been characterized for traits of interest. A simplified descriptors pocket-sized handbook was developed, adapted from the IBPGR/ICRISAT handbook (1992).

Identification of traits of economic importance

Ground-nut productivity in West and Central Africa is limited by a number of biotic and abiotic constraints. The most important are foliar diseases, Groundnut Rosette Virus (GRV), Peanut Clump Virus (PCV), *Aspergillus flavus*/aflatoxin contamination, and drought. The germplasm was therefore screened for sources of resistance to these biological challenges.

Foliar diseases

Among the foliar diseases, early and late leaf spots and rust are the most destructive in ground-nut worldwide (Wynne et al. 1991). Field screening of the germplasm for resistance to foliar diseases was conducted in partnership with NARS, at hot spots such as Niangoloko (Burkina Faso), Bengou (Niger) and Samanko (Mali). Other screening work was conducted by ICRISAT in India (Singh et al. 1997; Mehan et al. 1996) and Malawi (Subrahmanyam et al. 1995). A total of 166 lines resistant to rust, 80 lines resistant to late leaf spots and 30 lines resistant to early leaf spot were identified from over 10 000 accessions. A comprehensive list of resistance sources has been published as Groundnut Germplasm Catalogue Vol. 2 (Mayeux and Ntare 2001a).

Ground-nut rosette disease (GRD)

Ground-nut rosette disease is the most destructive virus disease of ground-nut in sub-Saharan Africa (Naidu et al. 1999). Epidemics are sporadic, but can cause total crop loss (Yayock 1975). GRD can be managed by the use of insecticides to control the aphid vector. Cultural practices such as early sowing and optimal plant density can reduce disease incidence. Unfortunately, smallholder farmers have been unable to adopt these options. The most cost effective solution is to use resistant varieties. The search for sources of resistance to GRD was carried out by ICRISAT in partnership with the Institute for Agricultural Research (IAR) at Samaru, Nigeria. Over 12 000 germplasm accessions were screened in the field in Nigeria and Malawi, using an infector row technique developed by Bock and Nigam (1983).

Resistance was identified in 130 long-duration Virginia types and 20 short-duration Spanish types (Subrahmanyam et al. 1998; Olorunju et al. 2001). These sources of resistance provide an opportunity to eliminate 30 to 100% of yield losses caused by the disease.

Aflatoxin contamination

Aflatoxin contamination of ground-nut is a hazard to human and animal health. Caused by *Aspergillus flavus*, aflatoxin has been a major hindrance to international trade in ground-nut. Work has concentrated on screening varieties and germplasm lines for resistance to invasion by *A. flavus* and subsequent aflatoxin contamination. This work was conducted at the ICRISAT stations of Sadore in Niger and Samanko in Mali. From a subset of 500 accessions grown for three years at Sadore, 74 accessions were consistently tolerant to *A. flavus* invasion and aflatoxin contamination. These will play a significant role in the integrated management of aflatoxin contamination, thus improving the marketability of ground-nut products in regional and international markets.

Enhancing availability of the genetic resources

International undertaking on distribution and exchange of germplasm

Designated germplasm

In the past, ground-nut germplasm exchange in West Africa was rare, fortuitous and not usually monitored. The development and distribution of improved ground-nut varieties also faced serious constraints. There are four classes of germplasm maintained and distributed by ICRISAT, namely gene bank accessions, breeding lines developed by ICRISAT, breeding lines developed in cooperative programmes, and a special class of breeding material acquired for use in crosses or to test in national and international trials.

After the coming into force of the Convention on Biological Diversity (CBD) in 1993, which recognizes sovereign rights of nations over their genetic resources, the germplasm collections held by International Agricultural Research Centres was placed under the auspices of the Food and Agriculture Organization of the United Nations (FAO) through an agreement to ensure their unrestricted flow for the benefit of the world community. The material covered by the agreement is referred to as ‘designated germplasm’. Out of the 6000 accessions conserved at ICRISAT-Niamey, 5037 are designated accessions.

Material transfer agreements

The designated germplasm and ICRISAT’s own breeding lines are freely available for distribution. In order to provide protection as international public goods, ICRISAT supplies these two classes of germplasm under a material transfer agreement (MTA). This is in compliance with the FAO/CGIAR agreement on CBD.

ICRISAT has traditionally adhered to a policy of unrestricted availability of germplasm held in its gene banks. In the interest of making this material available for future research and utilization, ICRISAT has undertaken not to claim intellectual property rights (IPRs) over the germplasm or related information. To ensure the continued availability of designated germplasm, ICRISAT has also agreed to pass the same obligation on to all recipients of designated germplasm. Accordingly, the recipient must agree:

- neither to claim ownership of the designated germplasm received nor to seek IPRs over the germplasm or related information; and
- to ensure that any subsequent person or institution to whom they make samples of the germplasm available is bound by the same provision.

Germplasm acquisition agreements

The ICRISAT regional gene bank accepts germplasm for medium-term conservation that can freely be transferred with MTA, as described above. The gene bank also holds for others under ‘black box’ arrangements for safety duplication, accession on which the donor of the germplasm has placed restriction. In such cases, the material is conserved, but usually will not be opened, examined, tested or used in research. Such material cannot be designated. There are a number of other options, such as

- freely available and available for acquisition from the gene bank;
- available only for research purposes and not to be distributed;
- available for distribution only on a regional basis; or
- seed to be stored in the gene bank but not for distribution

.The national collections of Niger and Mali are held under the last-named option.

Quarantine procedures for germplasm export

The success of international and regional germplasm exchange and utilization largely depends on its timely transfer and ease of mobility. A safe and rapid transfer of germplasm is vital for a sound crop improvement programme. However, introduced useful germplasm must not endanger the new habitat with exotic pests and diseases. Importing small quantities of seed for experimental purposes, with the appropriate safeguards based on sound biological principles, can often be a solution for improving the genetic base of crops.

Although there have been regulatory requirements for safe exchange of germplasm between different countries of the West African region since 1967, implementation has been difficult. This is due to various technical and resource constraints, as well as a lack of awareness among ground-nut researchers. To fill this gap, technical aspects of quarantine procedures were documented, in consultation with NARS partners. The information was compiled into a handbook to provide technical information on the necessity, and simple procedures that can be followed, for safe exchange of ground-nut germplasm, not only between West African countries, but also with other parts of the world.

Distribution of germplasm and improved ground-nut varieties

Distribution of germplasm remains of paramount importance and could be said to be the reason for the conservation of the collections. International attitudes toward germplasm have changed in the last decade, and there is a need to maintain distribution procedures that are in concurrence with these changes. Useful germplasm and improved breeding lines are made available to NARS and other beneficiaries in a timely manner (**Table 3**).

Table 3. Number of samples distributed from the regional gene bank to West Africa and other countries.

Originator	**Year**						**Total**
	1996	**1997**	**1998**	**1999**	**2000**	**2001**	
Algeria					4		4
Belgium		6					6
Benin	5			5			10
Burkina Faso			91	17			108
Central African Republic		25					25
Côte d’Ivoire			2			7	9
Democratic Republic of the Congo						30	30
Gambia		9					9
India	1					165	166
Kenya						6	6
Mali				233		71	304
Niger	22	1	9	7	12	202	253
Nigeria	2319	437	3	11	121		2891
Senegal		15		5			20
Sierra Leone			14			14	28
United Kingdom		2					2
ICRISAT in West Africa	2000			200	300		2500
Total	4347	497	119	478	437	495	6371

Lessons on development

A broad range of ground-nut germplasm has been assembled in the region to support future development. Breeders and other users now have ready access to a diverse gene pool for development of new varieties to meet farmer and market requirements. It is imperative that this resource be maintained at a sustainable level.

Cold storage, considered the best method of conservation, requires considerable investment, both for construction and for operation. The unreliable power supply in most parts of West Africa also makes it difficult to use cold storage efficiently. Thus, most national programmes in the region still lack basic germplasm conservation facilities, and assistance with basic facilities is vital. In the short term, NARS can use the regional gene bank to safely conserve their unique national working collections.

Accessibility to information is crucial. Sharing knowledge and information is essential to help extend new technology and provide feedback on consumer and producer needs. Databases developed on ground-nut germplasm make ready access to this resource a practical reality. Knowing what is available in the collections, and the traits and characteristics of the material, saves users precious time and energy.

Conclusions

The regional gene bank established under the auspices of the Common Fund for Commodities is a model for other crops. The maintenance, conservation and utilization of regional collections on a sustainable basis are imperative. The regional gene bank should serve national programmes that cannot afford to build and maintain such facilities at the national level. Material kept in the regional gene bank should be accessible at any time without special conditions except those agreed upon by the partners.

There is still a need to develop efficient documentation of information at the NARS level in the form of databases covering parameters such as prices, markets, seed laws, quarantine requirements, IPRs, input delivery systems and product quality.

There is a need to strengthen the capacities of lead NARS to serve as regional plant genetic resources centres and to establish mechanisms for their sustainable management.

Regional partnerships need to be further strengthened through subregional organizations, such as the West and Central Africa Council for Agricultural Research and Development (CORAF/WECARD). The genetic capital is rich and varied, and provides insurance against an unknown future. Thus the maintenance, conservation and utilization of this resource on a sustainable basis remain crucial.

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