TECHNOLOGY OPTIONS FOR SUSTAINABLE AGRICULTURAL PRODUCTION IN SUB-SAHARAN AFRICA

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OPTIONS TECHNOLOGIQUES POUR UNE PRODUCTION AGRICOLE DURABLE EN AFRIQUE SUB-SAHARIENNE

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PREFACE

This book brought together a wealth of scientific information on semi-arid agriculture. About sixty papers covering the broad areas of agricultural research, development and the management of natural resources were presented and discussed. Nearly thirty per cent of these papers were not acceptable for publication in this book.

The objectives of this Scientific Conference were to:

- Critically review and document the current state of knowledge and research approaches for developing ecologically sustainable and economically viable technologies that could accelerate agricultural production and productivity;

- Facilitate the exchange of experience in technology transfer, based on country-level case studies;

- Identify technical gaps and "missing links" for an effective transfer of research results into extension recommendations for adoption by farmers;

- Make an inventory of more productive technologies for the intensification of agricultural production in the 21st Century;

The workshop was attended by over 90 participants from 23 countries, Regional and International Research Organizations, including OAU, IITA, ICRISAT, ILRI, the Economic Commission for Africa and Universities.

Discussions on maximizing technology impacts in the first chapter, brought to the forefront policy issues, technology development and the need for agrarian reforms. The implications of the removal of subsidies on inputs and the devaluation of currencies on technology adoption and on overall agricultural production in the short and long-term were addressed. It was concluded that the impact of these implications will be positive in the long-run. Favourable agricultural development policy is, however, crucial in order to encourage farmers to adopt more productive and sustainable technologies.

The second chapter of the book surfaced available and potential technologies for increasing food grain production. The impact of the combined efforts of national research organizations, regional and international agricultural research systems on the generation and development of new cultivars and environmentally friendly technologies was highlighted. The technological options recommended included the combined application of improved agronomic practices (i.e. the of organic matter, rotation, etc.), chemical fertilizers, high yielding cultivars and development of an efficient seed industry to ensure food security in Africa.

Technology transfer and the role of agricultural extension were the focus of the third chapter which revealed that the evolution of agricultural extension systems in some countries lead to the success of technology transfer and adoption much associated with functional input supply systems, access to credits and diversified market opportunities.

The fundamental relation of activities between agriculture and environment is no longer separable. The fourth chapter of this book deals with the alternative approaches and available technologies for the development of sustainable agriculture, as a viable dynamic concept to enhance ecologically compatible economic growth. A number of papers have emphasized the need for integrating crops/livestock/and agroforestry systems to rejuvenate the resource base for sustained agricultural growth.

We hope that this book will be useful to a wide spectrum of institutions and experts involved in research, technology development and transfer, natural resource management, as well as to policy makers and informed farmers. Furthermore, it could be a valuable addition to libraries of agricultural research centres and universities in Africa.

Taye Bezuneh
Director of Research
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PREFACE

La présente publication est un recueil de riches informations scientifiques relatives à l'agriculture semi-aride. Environ soixante communications couvrant de vastes domaines de la recherche agricole, du développement et de la gestion des ressources naturelles ont été examinées. Près de trente pour cent de ces communications n'ont pas été retenues pour publication dans ce recueil. Cette conférence a eu pour objectifs :

- Evaluer systématiquement et documenter l'état des connaissances et les approches de recherche pour la mise au point de technologies écologiquement durables et économiquement viables, susceptibles d'accélérer la production et la productivité agricoles.

- Faciliter, sur la base des études de cas par pays, l'échange d'expériences en matière de transfert de technologies.

- Identifier les insuffisances techniques et les "chaînons manquants" pour une matérialisation des résultats de recherche en recommandations de vulgarisation et d'adoption au niveau des paysans.

- Recenser les technologies les plus productives pour l'intensification de la production agricole au cours du 21e siècle. Etaient présents à cet atelier, plus de 90 délégués de 23 pays, d'Organisations Régionales et Internationales de Recherche dont l'OUA, l'IITA, l'ICRISAT, l'ILRI, la Commission Economique pour l'Afrique et des Universités.

Le premier chapitre, examine les impacts des technologies à maximiser dans le domaine des questions politiques fondamentales, la mise au point de technologies et la nécessité de réformes agraires. Les implications de la suppression des subventions des intrants ainsi que de la dévaluation des monnaies sur l'adoption des technologies et sur l'ensemble de la production agricole a court et à long terme sont débattues. En conclusion, il est dit que l'impact de ces implications sera positif à long terme. Cependant, une politique favorable de développement agricole s'avère essentielle pour encourager les paysans à adopter des technologies plus productives.

Le deuxième chapitre passe en revue les technologies disponibles et potentielles pour l'augmentation de la production de cultures vivrières. Les efforts des organismes nationaux de recherche et des systèmes régionaux et internationaux de recherche agricole sur la mise au point de technologiques recommandées doivent porter sur l'application combinée de pratiques agronomiques améliorées (i.e. utilisation de matière organique, rotation etc.), les engrais chimiques et les cultivars de haut rendement ainsi que le développement d'une industrie semencière efficace pour la réalisation de la sécurité alimentaire en Afrique.

Ce troisième chapitre est axé sur le transfert de technologie et le rôle de la vulgarisation agricole. L'évolution des systèmes de vulgarisation agricole de certains pays a révélé que le succès du transfert et de l'adoption de technologies a été largement dû aux systèmes fonctionnels de fourniture d'intrants, à l'accès au crédit et à la diversifi-

cation des créneaux commerciaux.
La relation fondamentale entre les activités agricoles et environnementales n'est plus à démonter. Le quatrième chapitre se penche sur les alternatives et les technologies disponibles pour le développement de l'agriculture durable considérée comme un concept dynamique viable en vue de la promotion d'une croissance économique compatible avec l'environnement. Un grand nombre de communications ont souligné la nécessité d'intégrer les systèmes cultures/élevage/agroforesterie pour régénérer la base des ressources pour la croissance agricole soutenue.

Nous espérons que ce recueil sera utile au grand nombre d'institutions et d'experts engagés dans la recherche, le développement et le transfert de technologies et la gestion des ressources naturelles ainsi qu'aux dirigeants et aux paysans informés. Par ailleurs, il pourra constituer un apport inestimable pour les bibliothèques des centres de recherche agricole et les universités d'Afrique.

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Chapter I

Towards Maximizing Technology Impacts

Meeting Sub-Saharan Africa's Food and Agricultural Needs in the 1990's and Beyond: Future Policy Issues and Orientations

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Abstract

The prognosis for sub-Saharan Africa's food and agricultural situation for the rest of the 1990's and beyond is bleak. Rapid population growth exceeding 3.0 per cent per annum is expected to lead to declining per-capita food consumption levels. The region is expected to make little progress towards raising its low per capita food supplies. Incomes are not expected to rise fast enough to permit market imports to offset the decline. This paper maintains that this bleak forecast will not materialize only if African governments take the necessary measures now to ensure a sustainable increase of, at least, four per cent per annum in food and agricultural production during the next 10 to 15 years. The paper addresses the critical issues involved and identifies the future policy orientations to guarantee the achievement of this target.

Résumé

En Afrique Sub-saharienne, les perspectives alimentaires et agricoles pour le reste des années 90 et au delà s'avèrent sombres. Il est à prévoir que l'accroissement démographique rapide qui dépasse 3 pour cent par an entraînera une baisse de la consommation céréalière per capita. Selon toute vraisemblance, la région dans son ensemble enregistrera peu de progrès en ce qui concerne l'augmentation de ses ressources vivrières per capita traditionnellement faibles. Les revenus ont peu de chances d'augmenter assez rapidement pour permettre aux importations de compenser cette baisse.

La perspective ainsi présentée est-elle inévitable ? Cette communication maintient que ces prévisions funestes ne se concrétiseront pas si les pays de la région prennent individuellement et collectivement "le taureau par les cornes" et adoptent des mesures appropriées qui permettent de réaliser de manière soutenue au cours des 10 à 15 années àvenir un taux de croissance annuel moyen de quatre pour cent de la production vivrière et agricole. Est-ce possible ? L'Afrique Sub-saharienne peut-elle réaliser un taux de croissance aussi ambitieux au vu de son passé et de sa performance ? Les autres secteurs de son économie peuvent-ils enregistrer un taux de croissance assez élevé pour absorber l'augmentation de la production agricole ? Qu'arrivera-t-il aux prix agricoles?

La présente communication examine ces différentes questions et identifie les contraintes majeures à la réalisation du taux de croissance de quatre pour cent. En guise de conclusion, elle identifie les orientations politiques qui devront être mises en oeuvre pour que ce taux de croissance soit réalisé et soutenu.

Introduction

Over 250 million people in sub-Saharan Africa are living in poverty. This figure is expected to rise to over 300 million by the year 2000, if present trends continue. By the end of the decade, it is projected that almost one-third of the developing world's poor will be found in sub-Saharan Africa, compared to about 19 per cent today (IFPRI, 1994). Most of these people do not have access to enough food to meet their needs for a healthy and productive life, often going hungry and not knowing where their next meal will come from. They often suffer and die from diseases associated with hunger and poverty. In short, over the last two decades, sub-Saharan Africa has been facing a general deterioration in the standard of living manifested in increased levels of poverty and food insecurity.

Per capita food and agricultural production has been inadequate in the region. Since the early 1980s, per capita production has been declining steadily (Figs. 1 and 2). Over three-fourths of the countries in sub-Saharan Africa produce less food today than in 1980. This stagnation and retrogression is the harbinger of the region's current economic malaise, social decline and marginalization.

Because the food and agricultural sector dominates most sub-Saharan African economies in terms of contribution to GDP, employment and incomes, its growth and development are essential for the overall process of socio-economic development in the region. The food and agricultural sector must grow enough food and raw materials for Africa's rising population and new industries; produce exports that will earn the foreign exchange needed to purchase essential machinery and equipment and service foreign debts; and, as productivity increases, release labour and capital for the other sectors. The challenge facing African agriculture is, therefore, immense. Not only must it feed a population that is increasing at an annual rate of about three percent and will double in about 20 years, it must also provide employment for a rapidly growing work force - 50 to 80 percent of Africans earn their living from the land.

It has been estimated that, to meet this challenge, sub-Saharan agriculture must grow at a minimum average annual growth rate of about 4.0 percent during the next 20 to 25 years (ECA, 1989; Cleaver, 1993). Can this challenge be met? Can sub-Saharan Africa achieve such an ambitious growth rate, given its past record and performance? Can the rest of the economy grow at a sufficiently high rate to absorb the increased agricultural production that such a growth rate entails? What would be the implication of such a growth rate on the environment? How should future food and agricultural policies be oriented to meet the target? This paper examines these issues and questions and proposes guidelines on future policy orientation to address them.

Is a Four per Cent Growth Rate Possible?

Is a 4.0 percent annual increase in food and agricultural production over the next 20 to 25 years an achievable expectation in sub-Saharan Africa? In this section we examine the potentials and possibilities that exist for achieving such a target and draw conclusions as to its feasibility and sustainability.

Sub-Saharan African agriculture is mainly rain-fed with irrigated agriculture accounting for only three per cent of the total cultivated area. At independence, low population densities characterized most of the region. Today, however, the situation is changing dramatically in most countries. In countries, such as Togo, Benin, Rwanda and Burundi, the eastern parts of Nigeria, the industrial mining areas of eastern and southern Africa and a number of Island States such as Mauritius and Cape Verde, it is becoming increasingly difficult to expand local food production horizontally to keep pace with population growth. In these areas, increases in population density has necessitated a shortening of the fallow period, resulting in incomplete natural regeneration process of soils previously under cultivation and a consequent decrease in soil fertility. This underlines the need for a "research-based" agriculture that uses biological, technical change to increase land and labour productivity. What then are the prospects for the future for technological change in sub-Saharan African agriculture?

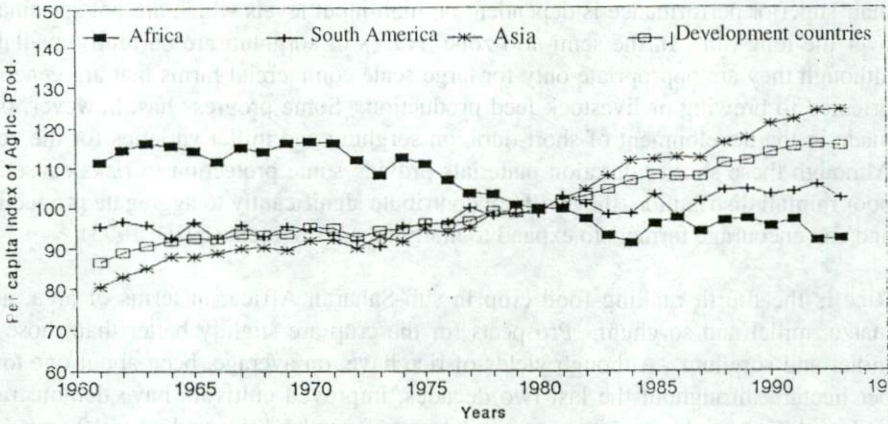

Figure 1. 1 Trends in per capita agricultural production (1979/81 = 100)

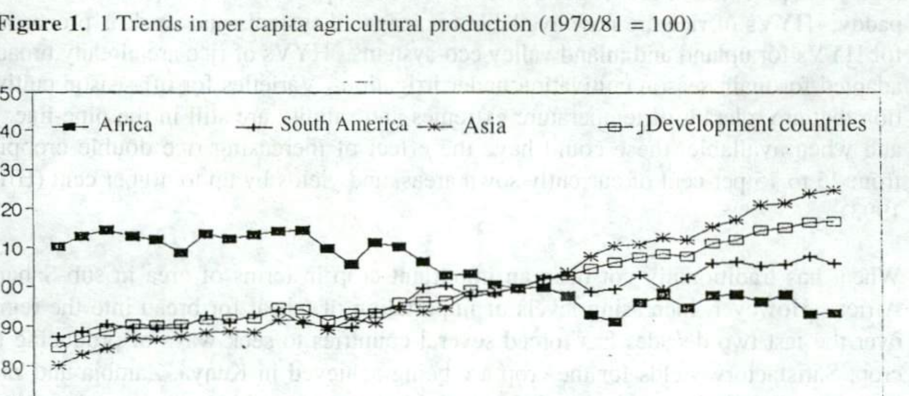

Figure 2. 2 Trends in per capita food production (1979/81 = 100)

Maize is among the few staple crops grown in the sub-region for which there presently exists a dependable improved technology. Research results have been promising and the improved varieties of the crop that made their appearance in the sixties have had the greatest impact on crop yields, particularly in the sub-humid zones (HIID,1993). However, the improved genetic materials available for maize for the humid zone require intensified cropping systems, which, unfortunately, may not be sustainable here as there are no known soil conservation technologies which are well adapted to the ecology of the zone.

The bright prospect for maize in the sub-region is in sharp contrast to those for sorghum and millet. Most of the countries of the region do not yet have improved technologies for both crops that are superior to those presently used by the majority of their farmers. Yet, these two crops are the most dominant staples of the region. While high yielding varieties (HYVs) of sorghum are currently available for the sub-humid zone, their superior performance is dependent on high input levels which are not sustainable over the long-run. In the semi-arid zone, HYVs of sorghum are currently available, although they are appropriate only for large scale commercial farms that are generally oriented to brewing or livestock feed production. Some progress has, however, been made in the development of short-duration sorghum and millet varieties for the zone. Although these shorter duration materials provide some protection to risks caused by poor rainfall distribution, they will not contribute significantly to aggregate production, and can encourage farmers to expand to marginal environment (HIID, 1993).

Rice is the fourth ranking food crop in sub-Saharan Africa, in terms of area, after maize, millet and sorghum. Prospects for the crop are slightly better than those for millet and sorghum. Although yields of rice have, on average, been about one tonne per hectare throughout the last two decades, improved cultivars have demonstrated high yield potential in the range of 3 to 6 tonnes for upland rice and up to 10 tonnes for paddy. HYVs of rice are now available for irrigated systems and work is proceeding for HYVs for upland and inland valley eco-systems. HYVs of rice are already broadly adapted for main season cultivation under irrigation. Varieties for off-season cultivation that are tolerant of temperature extremes and salinity are still in the pipe-line. If and when available, these could have the effect of increasing rice double cropping from 25 to 75 per cent of currently sown areas, and yields by up to 40 per cent (HIID, 1993).

Wheat has traditionally not been an important crop in terms of area in sub-Saharan Africa. However, increasing levels of importation of wheat for bread into the region over the last two decades has forced several countries to seek ways of producing the crop. Satisfactory yields for the crop are being achieved in Kenya, Zambia and Zimbabwe, while other countries, such as Chad, Madagascar, and Uganda have demonstrated that they can produce reasonable yields in some areas. Wheat yields are still, however, disappointing in the region as a whole, due to many as yet unresolved technical and management problems (CIMMYT, 1992).

Starchy roots and tubers are next in importance to cereals in the diets of much of sub-Saharan Africa, particularly in the humid zone. Since they make up an important part of the food basket in the sub-region and are the most competitive source of calories and protein with cereals, their production trends affect cereal requirements, and hence the relative significance of cereals production in countries of the sub-region. There appears to be under-utilized high yielding varieties of cassava, with potential for increasing production by as much as 50 per cent on about 50 per cent of currently planted areas in the humid zone. Good prospects also exist for sweet potatoes in the zone. In addition, improved genetic materials are available for cassava and sweet potatoes for the sub-humid zone (HIID, 1993).

Overall, it would appear that there is considerable scope for achieving significant and even dramatic increases in food and agricultural production in sub-Saharan Africa through increased yields. In the rain-fed farming systems, where fallow periods are no longer adequate to maintain soil fertility, the target growth in food and agricultural production will require the provision of adequate soil nutrients, combined with improved seed technologies and complementary practices to improve weed control, good plant population, and other cultural practices. It has been suggested that, given present knowledge and Africa's severe problem of soil degradation, there will be little choice but to depend heavily on external sources of nutrients (Desai, 1990). Already there is some evidence of rapid uptake of new seeds and fertilizer in a number of countries in response to better economic environments (Seckler, 1993).

Possibilities for meeting the target also exist through the extension of land cultivation. This possibility will obviously be naturally greatest in the least densely populated countries of the continent. The rough estimate is that it would be possible to achieve simple annual rates of increase in food and agricultural production of 1.0 to 1.5 per cent simply as a result of developing new land resources in the sub-region (Abalu, 1995). Investments in appropriate irrigated facilities would, of course, have the effect of revolutionalizing food production in some of these new lands.

There are several encouraging developments which suggest that the four per cent target is, indeed, achievable. In 1989, the World Bank reported that sub-Saharan Africa's agricultural production and exports during the previous two decades were growing at well above the long-term average of the 1970's and early 1980's (World Bank, 1989). Indeed, almost a third of the countries of sub-Saharan Africa are estimated to have had good to excellent growth rates (3.5 per cent and above) during most of the period 1986 to 1991, including an excellent performance by Africa's most populous country, Nigeria (Cleaver, 1993). An important question, however, is whether there are critical factors which will either prevent its achievement or mitigate its sustainability. These issues are discussed in the next section.

The Critical Issues

Sub-Saharan Africa has considerable untapped resources to assure revolutionary increases in food and agricultural production within the foreseeable future. It, however, takes more than mere potential to get the region's agriculture moving. While the creation of the right policy framework and environment is crucial, and we shall return to this later, there are other critical issues which must first be resolved or, at the very least, not overlooked. These include issues relating to: the region's high population growth rate; whether the non-agricultural sectors of the economies of the region will grow at a rate fast enough to absorb the increased agricultural production, and thus prevent depression in farm prices; whether or not there will be enough peace and stability in the countries of the region to guarantee an appropriate production environment; environmental considerations; and the capacity of the countries to analyse, formulate, implement and manage the policies that are needed not only to achieve the target growth rate but also and, perhaps more importantly, to sustain and build on it if achieved. These issues are discussed below.

The population growth issue

The 4.0 per cent growth target was chosen to reflect a 1.5 per cent growth rate in per capita production. This is intended to ensure that production keeps pace with the region's rapidly growing population. The plain fact is that the region will remain enthralled by the sheer demands of sustenance and survival, even with a 4.0 per cent growth in food and agricultural production, unless its population growth rate is significantly reduced.

The annual world population increase is expected to peak between 1990 and 2020. According to the United Nations Median Projections, 933 million people are expected to be added to the world's population during 1990-2000, 921 million during 2000-2010, and 900 million during 2010-2020. About 93 per cent of the population increase - 86 million persons per year - is projected to occur in developing countries. The highest growth rate of population in the developing regions will be in sub-Sahara Africa. Absolute increase in population between 1990 and 2025 in sub-Saharan Africa will be about 800 million (IFPRI, 1994).

Because of the critical relationship between food production, population growth and food consumption in sub-Saharan Africa, it is important to have a clear idea of what is happening to the African population? As of now the nature of this relationship is not very clear. A recent review of seventeen countries for which data are available for the period 1985 to 1990 suggests that fertility declined in about half of them in the 1990s (Cleland, *et al.*, 1994). Declines in Kenya, Zimbabwe, Botswana and in the black population of South Africa, as a result of rising contraceptive use, were clear cut. Appreciable decline also occurred in Sudan (North), primarily because of rising ages at marriage. Modest declines were recorded for Tanzania, Swaziland, Senegal and Nigeria. In the remaining countries for which data are available - Ethiopia, Uganda, Burundi, Mali, Liberia, Ghana, Togo, and Cameroon - no convincing evidence of fertility decline was reported. What does this very mixed picture of the fertility situation in sub-Saharan Africa suggest? At the very least it must suggest that the usual scepticism about the prospect for fertility decline in the sub-region must give way to more optimism and commensurate strategic policies. Consequently, efforts to attain dramatic increases in food and agricultural production in sub-Saharan Africa must be accompanied by effective family planning measures.

The absorbtion issue

Given the important role that the agricultural sector plays in almost all the economies of sub-Saharan Africa (often over 60 per cent of the national economy), its growth and the nature of its linkages with the other sectors of the economy are critical, not only for the performance of the other sectors but also for its own performance. For example, if agriculture is 60 per cent of the economy and is growing at 4 per cent, the rest of the economy will need to grow at 9 per cent if overall growth is to be 6 per cent.

The linkage between the agricultural sector and the other sectors of the economy in sub-Saharan Africa appears to be becoming increasingly dysfunctional. The share of agriculture in GDP which, under normal circumstances, should go down over time as economic transformation takes place, is instead either stagnant or going up in sub-Saharan Africa. For example, the World Bank's latest World Development Report (1994) estimates that the agriculture share in the economy in 1970 compared with the share in 1992 for Tanzania increased from 41 to 61 per cent, in Zaire from 21 per cent to 31 per cent, in Zambia from 11 to 16 per cent, in Zimbabwe from 15 to 22 per cent, and in Ghana from 47 to 89 per cent. Only in a few countries such as Burundi, Niger, Mali, Senegal and Cameroon did it go down during the period and not by much. When these figures are compared to the annual growth rates in agricultural GDP in the different countries during the period 1970 to 1992, a diverse but disturbing picture emerges. There appears to have been little linkage between agricultural growth and what is happening in the rest of the economy in sub-Saharan Africa. Sub-Saharan Africa appears to be de-industrializing and de-manufacturing. In this regard, the 1980s appear to have witnessed the birth of a fundamental structural change in sub-Saharan African economies and the region's agriculture ceased to be a key contributor to the growth process, whereas it was hitherto a significant contributor in the 1960s and early 1970s. Following this watershed period, the other sectors of the economies of the region appeared to have become increasingly incapable of synchronizing their activities with those of the agricultural sectors in line with the increase in agricultural growth that was taking place.

This calls into question whether a growth rate of 4 per cent, once achieved, can be sustained. It also calls into question the capacity of the other sectors of the economy to stimulate agriculture and give it a chance to continue to grow. All of these suggest inadequacies in the structure of existing macro-economic policies, exchange rates, and commercial policies. They also suggest a failure of local industry and manufacturing to generate the needed demand for agricultural products and the failure of policy and investment in infrastructures to enable that demand to be met through local production than through imports. As everyone very well knows, it is cheaper to import rice or maize from the US or Thailand than it is to bring it from the interior of most sub-Saharan countries, talk much less of carrying them across national borders. The obvious conclusion from this situation is that existing policies have failed to stimulate agriculture. The lesson here is that it is just not enough to blindly promote the continuation of existing policy reforms. Future policy orientations must first find out where and why these policies have failed before trying corrective measures. Africa's agricultural revolution needs the help of the other sectors of the economy to bring it about.

Peace and stability

The end of the "cold war," the discredit of the "command economy", the rediscovery of the "market economy" and the re-emergence of "democracy" in Africa have all combined to set the context for the on-going instability of many countries in sub-Saharan Africa. The region is presently going through a period of crisis and chaos. There is not a single country that is free from the endless catalogue of ills that make normal economic and agricultural activities difficult. Sub-Saharan Africa's traditionally proud and resilient people are today tormented by civil strife, political systems that do not work, refugees, drought, corruption, AIDS, and other untold sufferings. The region is thus in a permanent state of war or other forms of instability.

These are, however, man-made problems. The civil wars, corruption, and bad governance confronting the region may be linked to a search for an African solution to African problems following the continent's colonial past that, to some extent, prevented Africans from thinking through their own problems and forced them to adopt a system of values and cultures that were alien to them. Natural problems such as desertification, drought, poor rains, etc. have only compounded and exacerbated an already bad situation. Given this kind of instability and uncertainty, is it realistic to expect the countries of the region to be able to successfully tap the huge potentials that exist in their agricultural sectors? Can dramatic increases in food and agricultural production be achieved and sustained without a clear and unambiguous movement towards lasting peace and stability in the region as a whole?

Environmental degradation

Sub-Saharan Africa possesses a varied environment comprising diverse ecological systems. Tropical forests, cool highlands, humid coastal areas, riverine and marshy zones, extensive savannas, semi-arid regions, and vast stretches of desert exist side by side throughout the region. This varied topography, super-imposed on highly variable soils and rainfall, has resulted in a wide combination of production systems and sub-systems including cultivation, herding, hunting, and gathering. The diversity has given rise, over time, to a wide variety of human activities which seek to exploit local and sub-regional specificities to achieve food security and sufficiency. As a result, contrasting systems involving shifting cultivation, intensive agriculture, organic fertilizer, intercropping, mixed farming, hill side, wetland and dry plains cultivation, water harvesting and irrigation, soil and forest conservation, and nomadic and transhumance pastoralism, now form part of the traditional production systems of African communities.

It is now, however, clear that environmental degradation caused by soil erosion, desertification, deforestation and unwise agricultural practices is seriously undermining the very resources on which many sub-Saharan African farmers and their families depend for their survival. It is also becoming increasingly obvious that, to be successful and sustainable, any effort to increase food and agricultural production in Africa to keep pace with the increased demands of the population, must be strongly linked to complementary strategies to sustainably manage the natural resource base.

Available evidence (McNamara, 1990; Anderson and Grove, 1987) suggest that environmental constraints are already posing serious limitations to agricultural production in several sub-Saharan countries, particularly in areas where population densities are increasing rapidly. In many of these countries, high population growth rates are already putting excessive pressure on the land. The consequence has been environmentally damaging levels of deforestation and land degradation. Rangelands are being destroyed as a result of overgrazing and wasteful and inadequate management of available water resources. The problem has been compounded by reduced and uncertain levels of rainfall which are aggravating the already deteriorating status of other natural resources. The worsening situation is also being accelerated by destructive cultural practices leading to severe soil problems and loss of valuable agricultural land. Sub-Saharan Africa's ability to dramatically increase and sustain its food and agricultural production will, therefore, depend heavily on the effectiveness of African efforts in reversing this trend and in managing the natural resource base.

Policy analysis, formulation and management capacities

In many sub-Sahara African countries, there are not enough of the highly trained managers, technical experts and economists needed to understand, plan, implement, monitor and modify food and agricultural policies on a continuing basis. Even where a few such individuals exist, they are often inappropriately utilized. Furthermore, the work ethics, high professionalism and selfless interest that are required to achieve revolutionary increases in agricultural production are virtually non-existent among many of the agricultural civil services and within the private sector in many sub-Sahara African countries. There are many reasons for this unsatisfactory situation, including poor remuneration and compensation and no or inequitable opportunities for promotion and upward mobility. Whatever the reasons for it, the end result is usually low morale, misplaced ideals and misuse of public funds. Is it possible to develop, in many sub-Saharan countries, a cadre of trusted and respected agricultural administrators at all levels to guarantee the much needed capacity for the analysis, formulation and management of sound policies for the agricultural sector?

External forces

The external environment has traditionally influenced sub-Saharan Africa's strategy for food and agricultural production. Most countries of the region depend on an agricultural trade surplus to finance their imports and to service their debts. UNECA (1995) data suggest that there are two major trends in the external arena which should be causes for alarm. First, the total outstanding external debt of sub-Saharan Africa stood at US$270 billion in 1990. This debt cost the region US$23 billion to service in 1991. The share of multilateral debt in the region's aggregate debt stock rose 24 per cent in 1993. This compares to 20 per cent in 1992 and 19 per cent in 1991. The external debt to GNP ratio, the debt to export ratio, and the debt service to export ratio have all been rising since the 1980s. Meanwhile, official development assistance (ODA) flows are on the decline. Second, the share of sub-Saharan African trade has fallen from about 4 per cent at independence to only 1.7 per cent in 1994. What is worse, intra-African trade amounted to only 5 per cent of total African trade in 1994.

The rising debt burden in the face of falling values of the continent's raw materials exports, reductions in market shares, worsening terms of trade, the development and increasing acceptance of synthetic substitutes for many of the region's products, inadequate international capital flows into the region, breakthroughs in biotechnology and lack of significant progress towards more effective intra-regional cooperation and integration all point to major external bottlenecks over which the countries of the region have little or no control, but which will affect their capacity to increase and maintain their agricultural productivity and production. Can an African agricultural revolution take place in the shadow of the region's huge debt overhang? Will sub-Saharan Africa be able to face the challenges that are being imposed by emerging and more competitive global markets?

Required Orientation of Future Policies

We dwelt on the critical issues raised above, not to raise doubts about sub-Saharan Africa's ability to rise out of its present predicament, but because we believe that it is our understanding of these critical issues that would shed useful light on the future orientations in policies that must be pursued.

There is presently an absence of the kind of coherent national policy frameworks that will usher in and sustain dramatic increases in food and agricultural production in sub-Sahara Africa. For example, inappropriate pricing, and tax policies often encourage excessive use of inputs, over-exploitation of land, as well as environmentally degrading cropping and livestock production patterns. Research results suggests that "good" food and agricultural policies, including policies associated with agricultural institutions, infrastructures, and human resources development, influence farmers in deciding which type of production technologies to adopt or adapt, as well as the choice of the techniques to use. New and more imaginative orientations in the policy environment in these areas are needed to dramatically broaden the adoption and diffusion of the required production technologies to substantially increase output per hectare of virtually all agricultural products produced in the region.

The fact is that the achievement of a sub-Saharan African agricultural revolution can only come from better domestic policies which result in higher food and agricultural production, higher economic growth, and lower population growth. In the past, the elements of the policy environments on offer to sub-Saharan African countries have varied, depending on the institutional context of the interested parties. Common elements in most policy prescription packages for sub-Saharan Africa have, however, included: reform of price, exchange rate, marketing and input supply policies to provide incentives for private sector investment in farming, marketing and processing; improved security of land tenure to induce conservation investments and improve access to credit; increased investment in research and extension, rural infrastructures, and human development (including, education, health and nutrition); and improved management, priority setting, and agroclimatic targeting of research and extension efforts (Rosegrant and Agcaoili, 1994).

Indeed, most sub-Saharan African countries have, during the past 10 years, attempted to apply these reform measures with the assistance of the World Bank and the International Monetary Fund. Ten years ago both of these institutions, as well as most of sub-Saharan Africa's other "givers of aid" insisted that the appropriate policies for the region's agriculture was to get the prices right, open up the markets and devalue the exchange rate. They had no doubt about the eventual beneficial outcome of these policies and many sub-Saharan African countries obliged and implemented them. Today we know better. It must be obvious to any objective observer that this very simplistic policy approach has not worked in sub-Saharan Africa. New orientations are, therefore, needed. Below we outline the main elements that could guide these orientations.

Measures to empower farmers

Experiences from Africa and elsewhere inform us that in most situations, where ordinary farmers have succeeded in raising their productivity and their standard of living, they have first acquired political muscle and influence. In sub-Saharan Africa, lip service to the plight of the region's farmers abound, with very little progress to show for it. However, in the few African countries where farmers have been empowered in the political process, they have been able to develop viable farmer organizations and other political constituencies that have been powerful enough to successfully make the case in the political arena for significant and sustained public investments in agriculture and in the rural communities. Zimbabwe is a good example. This is particularly important, given the huge investments that are still needed in many countries of the region to develop the human resources and install the institutions and infrastructures that are needed to allow the agricultural sector to grow rapidly.

The development and/or adaptation of new farm technologies

Many African farmers are still using low yielding agricultural technologies which contribute not only to low production but also to reduced labour productivity. Why, one must ask, despite the billions of dollars that have been spent on national and international research to improve agricultural technologies in sub-Sahara Africa, is the situation not improving much? Logic would suggest that the stumbling block here may not be agricultural research itself but the linkage between agricultural research and the farm. If this is true, then the International Agricultural Research Centres and the National Agricultural Research Systems have been a big disappointment. Where is the transfer of technology that we all talk about? Where is the training that the Consultative Group on International Agricultural Research (CGIAR) institutions frequently use to justify their budgets? Where is the capacity building in national programmes which is so essential for technology transfer and sustainability? What has happened to the dreams of farming systems research and on-farm adaptive research which, just a few years ago, seem like the panacea for the region's technology generation and adoption problems?

National systems must commit themselves to long-term public and private investments in agricultural research, as well as to a systematic effort in introducing improved technologies from the existing global research stock and adapting them to local conditions. There cannot continue to be business as usual for many of the CGIAR centres which service sub-Saharan African agriculture. They must, in future, not only be concerned, but more importantly, their strategies and work programmes should be seen to be oriented towards the business of technology transfer and capacity building in the countries of the region. In this regard, the emphasis every where should be on the communication of research results to farmers in a useable form and the establishment of the national and international means to enhance research-extension-farmer linkages and the efficiency and relevance of technology generation and transfer.

Given the limited available financial and, in particular, human resources and, thanks to existing experiences of the newly transformed economies of Southeast and South Asia, sub-Saharan Africa does not have to continue to spend scarce resources on basic research in genetics, plant physiology, biotechnology, etc. The future orientation should be towards a concentration of efforts around adaptive agricultural research. The objective should be to develop, in stages, national research services covering all sub-sectors and focused sharply on the needs of each country's different agro-ecological zones and production systems, supported on a broad front by regional and international research arrangements.

Improving the performance of critical institutions

To achieve its food and agriculture goals, national policies and strategies must be supported on a broad front by a set of institutions, both public and private, which provide economic and other services, to directly or indirectly influence the success of the farmers involved. These institutions must make and implement strategic decisions that influence the allocation of resources, regulate and stabilize socio-economic processes, adjucate between competing interests, and convert public resources into common benefits. Renewed public and private investments geared towards improvements of the performance of institutions involving marketing, credit, research, extension, and land reform are, therefore, essential.

With regards to marketing, the future policies should ensure that farmers have easy and ready access to national, regional and international markets. At the national level, the orientation should be towards: more efficient rural transport systems; the development of storage facilities; reduction of transaction costs, including formal and informal "non-tariff" barriers; and better market intelligence. At the regional level, the focus should be on: wholehearted and serious implementation of existing regional integration agreements; better market intelligence; and support for increased intra- and inter-regional trade through the elimination of tariff and non-tariff barriers, and a better and faster response to changes in regional demand and consumption preferences. At the international level, the orientation should be towards a better understanding of the workings of global markets, including the nature of the evolving competition environment and how to cope with, and survive in it; and better negotiating African capacities and skills to ensure fairer access to world markets.

In respect of extension, the orientation should be towards a pragmatic approach and strategy which experiments with a number of alternative extension approaches, as opposed to current World Bank preference for, and practice of, one universal model. Such an orientation is not only wise but also prudent in the face of resource constraints imposed by operating structural adjustment programmes in many sub-Saharan African countries. Many of these countries would benefit more from a flexible approach which experiments with different extension models and extension-farmer ratios and whose major objective is to develop cost effective ways of providing extension services to the majority of each country's farmers.
Future policy orientations should also ensure easier access to credit and agricultural inputs, such as seed and fertilizers, through the encouragement of alternative group action by farmers such as joint ventures, cooperatives, farmer associations, etc. to improve the bargaining power and position of the farmers.

Effective capital investments in physical infrastructures

Physical infrastructures or social overhead capital, as they are sometimes called, provide services which are critical for the attainment of national and regional food and agriculture production goals. The contributions of physical infrastructures in reducing the cost of marketing food and agricultural products in Africa are obvious and well known. Imperfections in rural labour markets can often be traced back, in most sub-Saharan Africa countries, to inadequate infrastructures. A network of well maintained rural roads is essential for the timely delivery of the fertilizers and other purchased inputs, that are so vital for increased production, and for the prompt evacuation of farm produce to minimize post-harvest losses following bumper harvests made possible by the adoption of improved agricultural technologies. Appropriate investments in physical infrastructures, such as rural roads and irrigation facilities will, therefore, deliver major benefits in food and agricultural production growth, poverty alleviation, and environmental sustainability, provided these investments respond to the felt needs and constraints of the farmers and of the area.

Development of human capital

Many sub-Saharan African agricultural training, health and other social institutions have just simply broken down. Human resources development in the agricultural sector is fundamental to longer-term sustainable growth in food and agricultural production. This will become even more important in the future, with the globalization of production and the increasing importance of human capital. Investments in rural health and education are, therefore, critical not only for sustainable increases in food and agricultural production but also for long-run sustainable reduction in poverty. To be effective, however, these investments must be allocated efficiently across activities, regions and ethnic groups. Furthermore, sensitivity to gender considerations is critical because the building of much neglected female human capital has a significant impact on the welfare of other members of the household, particularly children, including their long-term production and income-earning prospects.

Land tenure

The present land tenure situation is unsatisfactory in many countries of the region. Sub-Sahara African Governments would need to take action to ensure equity in access to land to provide incentives for their conservation and improvement. In many countries, it will be necessary to establish clear rules on access, ownership and use of land particularly by women. In some cases, this may require individual title deeds while in others there may be need for formalization and effective enforcement of traditional systems of land tenure and use. Under some circumstances, it may be necessary to evolve new property rights regimes and build new institutions to ensure their implementation.

Conclusion

Sub-Sahara Africa's economic malaise is first and foremost a malaise of the inability of the region's agriculture to continue to contribute to the overall growth process in the region. The decline in food and agricultural production over the years has become synonymous with the region's stagnation, social decline and marginalization in the world. Unless renewed measures are taken by the Governments and people of the region to dramatically increase agricultural production, there will be continued deterioration and stagnation throughout the region. Concerted efforts are needed not only from within the region but also from the international community to ensure that the right mixture of policies are put in place to promote and sustain a minimum annual rate of increase of food and agricultural production of at least 4 per cent per annum during the rest of the 1990s and beyond.

The potential exists for attaining and sustaining such an ambitious growth rate, provided there is peace and stability and the political will exists. Furthermore, renewed efforts are needed to slow down the growth in population and to ensure that the environment is protected. It, however, takes more than family planning measures, peaceful coexistence, the greening of Africa and empty political rhetoric to feed Africa. These have to supported by the right mix of policies to achieve and sustain the target rate of growth through accelerated investments in agricultural research and technology aimed at yield enhancement and stabilization, the development of rural infrastructure, the strengthening of rural institutions, and adoption of policies that will facilitate access by farmers to land and modern inputs, improve farm management, provide necessary production incentives, and enhance exchange of goods and services between urban and rural areas, between and among the countries of the region, and between the countries of the region and the rest of the world.

There is no doubt that if rapid agricultural growth is to be achieved and sustained in sub-Saharan African countries, concerted action and joint efforts would be required so that the different countries in the region can develop within a common framework that takes cognizance of their peculiar needs. It should now be obvious to everyone that African countries working alone would find it very difficult to revolutionalize their agricultural sectors. In this regard, the continent cannot afford to be left out of the general world trend towards regional trading blocks. This is particularly true with respect to the attainment of their food production objectives. Increased trade among African countries, collaborative agricultural research programmes, the implementation of joint food security strategies, and joint natural resource management, particularly river basin development, are just a few areas where regional cooperation would be essential for meeting the future food needs of the sub-region.

Unfortunately, sub-Saharan Africa has not had a particularly good record with respect to cooperation in this area. Although most of them have long recognized the importance of regional cooperation and indeed have entered into a variety of agreements, old traditions and the absence of long-term political commitment have prevented them from translating the noble objectives of these agreements into concrete actions. On the contrary, many sub-Saharan African countries have become so used to food and other assistance from the developed world that they have become incapable of thinking seriously in inter-African or south-south terms. The fact is that, as long as the agricultural and economic relations of sub-Saharan African countries remain strongly oriented to the developed countries, regional cooperation in Africa will continue to be a programme of wishful thinking, and the much needed dramatic and sustainable increases in food and agricultural production a distant dream.

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Technology Development for Semi-Arid Sub-Saharan Africa: Theory, Performance, and Constraints

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Abstract

The paper proposes a theory of technology development for semi-arid regions. It then evaluates the theory by reviewing the characteristics of technologies successfully introduced into the regions. Modeling is then used to identify some constraints to further technology introduction of the type proposed. Some specific policy recommendations to accelerate technology introduction are made.

Résumé

Cette communication propose une théorie de mise au point de technologies pour les régions semi-arides. Elle évalue ensuite la théorie en question en analysant les caractéristiques des technologies introduites avec succès dans ces régions. Puis le système de modèle est utilisé pour identifier certaines contraintes à l'introduction ultérieure de technologies du genre proposé. Quelques recommandations spécifiques d'ordre politique sont formulées en vue d'accélérer l'introduction de technologies.

Introduction

Declining food production per capita over the last three decades, especially in the Sahel, but also in other parts of sub-Saharan Africa, leads many to be pessimistic about future agricultural performance in this region. High population growth turns even moderate agricultural-production growth rates into declining per-capita trends (Sanders and Ramaswamy, 1995). The per-capita declines have been especially serious in the semi-arid regions where rainfall is low and irregular, and soils are often fragile with low fertility. Historically, these regions have been contributors to the labour pool of the more prosperous higher-rainfall regions through out-migration. However, there have been some successes in agricultural performance in this semi-arid region. A closer look at these successes is useful to formulate approaches to technology development and leads to some optimism about the future of agricultural development in semi-arid, sub-Saharan Africa.

This paper formulates a theory of technology development for the semi-arid, sub-Saharan region of Africa and evaluates this theory. First, the adequacy of the theory in explaining observed technology successes in semi-arid West Africa is reviewed. Secondly, potential technologies of the type recommended are modeled, and the predictions from these models are compared with the observed shifts in technology. The last two sections of the paper make some policy recommendations and conclusions.

A Theory of Intensive Agricultural Technology Development.

In the semi-arid regions of sub-Saharan Africa, the principal constraint to crop productivity is almost given by definition. Semi-arid regions have inadequate soil water[1] for most crop production in some years or during some of the crop seasons. The effects oi low and irregular rainfall on crop yields are frequently aggravated by soil crusting, which leads to reduced water infiltration. In these crusted soils, water-retention techniques such as dikes and ridging become critical to reduce runoff and to use the available rainfall. Fortunately, there are numerous techniques for water conservation or retention, and these are potentially very important (Carr, 1989; Reij *et al.*, 1988; Sanders *et al.*, 1990).

Making water available when nutrient levels in the soil are very low often results in only a small yield response. Even at slightly higher nutrient levels, cereals will quickly deplete the available nutrients. Conversely, applying fertilizers (organic or inorganic) without an assured water supply is economically risky because the response to fertilizer depends upon the availability of water at the critical stages of plant development.

Combined technologies to increase soil water and crop nutrient levels have been shown to raise sorghum yields 50 to 100% and to be highly profitable (Sanders *et al.*, 1990; Nagy *et al.*, 1988). These combined technologies are land substituting and increase the demand for labour. To what extent would these technologies be profitable and fit into farmers' production systems in the semi-arid environment of West Africa?

The semi-arid regions of West Africa have had an increasing population pressure on the land, causing a breakdown of the traditional fallow periods of 10 to 15 years. Shorter fallow periods, without replacing soil nutrients with purchased inputs, cause crop yields to decrease over time. Farmers must then increase their cultivated area to maintain production levels, thereby pushing crop production into more marginal areas and, thus, decreasing communal grazing areas. As cattle are sold or entrusted to migrating herders, availability of manure as fertilizer declines.

Soil-nutrient depletion, leading to lower yields, becomes a widespread problem with increased population pressure (Southgate *et al.*, 1990). As cultivated areas are extended, wind and water erosion, as well as soil crusting, often occurs as farmers intensively cultivate the previously marginal crop or grazing areas and follow the traditional cultural practices of utilizing or burning crop residues. With declining organic matter and soil nutrient levels, farmers must increase their labour inputs to maintain the same level of production (Sander *et al.*, 1990).

The induced innovation theory considers technological change to be responsive to the economic signals from relative factor and product prices. In this case, the reduction in

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[1] In the last two decades there has been little investment in irrigation in this region, mainly due to prohibitive costs (Matlon, 1987, p. 66). Both construction and rehabilitation of existing chemes were estimated to cost between $5,000 and $20,000 per ha in the 1980's (Matlon, 1990, p. 19).

availability and quality of land, and reduced productivity of labour, induce researchers and governments to produce and promote, and farmers to adopt, new technologies which substitute increased use of labour and/or inputs for degraded land. Critics of the more intensive water-retention technologies recommended above have emphasized the large increases in labour requirements (Matlon, 1990). This labour-use change is substantial. However, the soil degradation and the consequent fall in the marginal productivity of labour already required an increased amount of labour to produce the same level of output with less land. Thus, it is soil degradation and the decreased value of farm-family labour, with few non-farm alternatives, that result in the increase in labour use. The technological change is a response to this demand for a technology that substitutes for land.

Recent Introduction of Intensive Technologies: A Preliminary Evaluation of the Theory

In the previous section, the principal constraints to output increases in semi-arid, sub-Saharan African agriculture are hypothesized to be water and soil nutrients. Are the new technologies being successfully introduced in semi-arid West Africa consistent with the above theory ?

The Semi-arid region with the most rapid technological change, the Sudano-Guinean zone, has the highest rainfall. Technically, this zone is in the transition to semi-humid rather than semi-arid, so fertilization can be practiced with less concern for first improving water retention. Here, the introduction of new cotton cultivars has been combined with increasing levels of chemical fertilizer application (Table 1). Moderately high levels of inorganic fertilizer were utilized on both cotton and maize. Sorghum often benefits from being in the rotation. Introduction of new cotton and maize cultivars, along with use of better production practices, then complemented the yield effects of increased fertilizer application, enabling substantial increases in cotton and maize yields. New technology development and diffusion have been very successful in this region.

Dikes to slow runoff have been rapidly introduced in the last five years in the Sudanian and the Sahelo-Sudanian regions in Burkina Faso and Niger. In northern Burkina Faso alone, there presently are 60,000 ha with these dikes (World Bank, 1989; Sanders *et al.*, 1990)[2]. Dikes are predominantly found in the most severely degraded regions and are constructed in the off-season when opportunity costs of family labour are generally lower than during the crop season. This is consistent with the theory presented earlier. In the most degraded regions, the available opportunities for labour are much fewer compared to areas with more adequate resources. Hence, sufficient labour becomes available for these extremely labour-intensive technologies only with soil degradation and low opportunity costs. In the Sudanian zone of Mali, animal traction with oxen is predominant in contrast with the almost exclusive use of donkeys in the Sudanian zone

[2] These dikes are constructed on the contour at fairly wide intervals of 10 to 30 meters, depending on the slope. The dikes accumulate soil from higher up on the toposequence behind them. This soil accumulation is often accompanied by the application of organic fertilizer (Wright, 1985). These combined techniques respond to both of the key constraints: water availability and soil nutrient level.

of Burkina Faso. In Mali, the use of ridging on the contour with animal traction is undertaken during the crop season when cultivating for weeds and has been shown to have almost as large a yield effect as tied ridges. As with the dikes and ridging, the collection and spreading of the manure available from larger herd sizes requires large labour input (Sanders, 1995).

Table 1. Rainfall by region and technologies successfully introduced in the 3 principal agro-ecological regions for crop production of the semi-arid tropics in West Africa.

Zone	Expected rainfall At 90% probability (mm)	Technologies	Responses to principal constraints	
			Water availability	Soil fertility
Sudano-Guinean	800-1100	New cotton and corn cultivars with chemical fertilizer and improved agronomic practices. Rapid increase in use of organic fertilizers.	Sufficient rainfall in most years in this zone	Fertilizer used in the combined-technology package
Sudanian	600-800	Contour dikes and organic fertilizer. Early cereal and cowpea cultivars. In Mali, ridging and increases in organic fertilizers.	Holds the runoff water. Earliness gives drought escape.	Organic fertilizer. Selected for low soil-fertility conditions.
Sahelo-Sudanian	350-600	Suplementary irrigation[A] Early cereal and cowpea cultivars and p fertilizer. Contour dikes and organic fertilizers.	Full water control. Drought escape with earliness. Holds the runoff	Rice heavily fertilized. In several regions, chemical fertilizers are being introduced. Organic fertilizers.

[A] only small areas of supplementary irrigation (<1 ha) provided by the government of Niger to farmers; these are a type of income stabilization for dryland farmers.

Another important innovation, in both the Sudanian and the Sahelo-Sudanian zones, has been the development of shorter-season cultivars of sorghum, millet, and cowpea. There has been diffusion of new cultivars both between farmers and from the experiment stations (Vierich and Stoop, 1990; Matlon, 1990; Coulibaly, 1987). Since the start of the drought of 1968-73, rainfall has been one standard deviation below the long-term normal in semi-arid West Africa (Glantz, 1987). Hence, the payoff from early or short-season varieties has increased, since earliness allows drought escape. Moreover, improved farmer cultivars have been selected under low soil-fertility conditions. Therefore, the early cultivars are a partial response to both constraints of water availability and soil nutrient levels. Thus, introduction of new cultivars alone gives only small income increases in average years of good rainfall but raises yields in adverse rainfall seasons. This is only a temporary solution as all cultivars need fertilizers or they will mine the soil nutrients. Now, in the sandy dune soils of the Sahelo-Sudanian zone of Niger, chemical phosphorous fertilization is being rapidly introduced in several regions (Mokwunye and Hammond, 1992). Here crusting is less common, so fertilizer use alone is less risky than in the Sudanian zone (Shapiro *et al.*, 1993).

Due to high capital, maintenance, and recovery costs of irrigation, only small-scale and supplementary irrigation has been promoted in Africa during the last two decades.

Nevertheless, in some regions, old irrigation projects have been important for farmers. In Niger, irrigation projects frequently serve as an income base for dryland farmers. In one zone, each farmer was given 0.4 ha of irrigated area; the farmers also produced crops on 4 to 5 ha of dryland. On the irrigated area, farmers produced rice using improved cultivars and high levels of chemical fertilizer. Clearly, these technologies resolved both constraints (Shapiro *et al*., 1993).

In summary, sub-Saharan Africa is usually considered a land-surplus region, with seasonal labour availability as the main constraint to increased output. However, in semi-arid West Africa, the general failure to adopt animal traction, except where intensive, yield-increasing technologies were introduced, may indicate the need for re-evaluation of this conventional analysis. The major thesis here is that the principal constraints to increasing agricultural output in much of sub-Saharan African agriculture are water availability and soil nutrient level. In semi-arid regions, improving soil nutrient level generally requires increased water availability at critical times of crop production, as well as higher nutrient levels. Water-retention or conservation devices tend to be extremely labor-intensive. Hence, they have been adopted first in those regions with land degradation and high population pressures where labour has the fewest alternatives. In regions with lower population densities and better resources, other technologies to increase water retention are expected to be adopted as the available crop area for expansion decreases and the value of agricultural products increases.

Potential Technologies and Constraints in the Sudanian Region.

There are many other high-yielding, water-retention/soil-fertility techniques besides the dikes/organic-fertilizer combination, including the combination of tied ridges and inorganic fertilizer. Tied ridging is a water-retention device constructed by creating perpendicular ridges, leaving a depression in the middle where water collects rather than running off[3]. As the available land is reduced with higher population pressure, model results predict an increasing area shift into the more intensive new technologies of tied ridges and fertilization. These combined technologies would be adopted by farmers, according to the model, and they provide moderate income increases even where there is severe degradation. Higher-population pressures leading to decreasing land availability will induce more rapid shifts to the new technologies proposed (Ramaswamy and Sanders, 1992).

Another critical factor affecting technology introduction is the profitability of agriculture. As output and input prices are changed with improved transportation and new policies, model results indicate that farmers shift to more intensive production practices, extending the area in tied ridges and increasing fertilization (Ramaswamy and Sanders, 1992). In the past, many African parastatal marketing agencies were not as concerned with the profitability of agriculture as with keeping food prices low and taxing agriculture to pay for public investments and services in urban areas (Bates,

[3] A similar very labour intensive technique of digging small holes in the field ("zia") and planting around them has also been adopted in the degraded Sudanian regions of Burkina where farmers have utilized the rock and stone dikes. Again the labour input is undertaken outside the crop season.

1981; World Bank, 1986). Increased profitability of agriculture does result in the more rapid adoption of more intensive technologies.
Our model results are confirmed by numerous field observations in the Sudanian region. First, as reported earlier, the dirt-and-stone dikes, combined with organic fertilizers, are being rapidly introduced on the Central Plateau of Burkina Faso, as is ridging on the contour with animal traction cultivators in Mali. Moreover, field studies in Burkina Faso during the 1980s indicated farmer adoption of several other intensive techniques, including the growth of a cash market for manure in Fulani regions, some utilization of inorganic fertilizer on sorghum, and increased out-of-season fruit and vegetable production with supplementary irrigation. The latter used organic fertilizer and watering by hand (Vierich and Stoop, 1990). Moreover, in the early 1990s, farmers introducing new maize cultivars with fertilizer have also been reported using tied ridges on the Central Plateau (Berry, personal communication, 1993). The areas in tied ridges have been expanding slowly as this is an extremely labour-intensive practice that has to be performed at one of the two peak labour-demand periods. Expanding the areas in these intensive technologies in the Sudanian zone of Burkina Faso may require not only increased water availability and higher soil fertility but also an animal-traction ridger to overcome the seasonal labour constraint.

The model results for potential technology introduction are consistent with our theory of technology development. The difficulty of simultaneously introducing three new inputs (a water-retention technique, fertilizer, a new animal-traction implement) may explain previous failures in technology introduction (Byerlee and Hesse de Polanco, 1986). Now, with increasing pressure on the land, and African governments being encouraged by funding agencies to create a more profitable environment for agriculture, several of these intensive or yield-increasing technologies are being adopted. This process needs to be adapted to different soils, labor availabilities, and economic environments (Sanders *et al.*, 1990; Shapiro *et al.*, 1993).

Accelerating the Introduction of Inorganic Fertilizer

In the agroecological zones discussed in the last two sections, a key technology component was inorganic fertilizer. Numerous alternatives to inorganic fertilizer have been researched. Most would substitute locally produced materials, by-products, or sophisticated production techniques such as inoculation. Many are claimed to be lower-cost or lower-risk. Unfortunately, in evaluating these alternatives in field trials in the Sahel, inorganic fertilizer was still the only viable alternative for increasing yields (Nagy *et al.*, 1988; Deuson and Sanders, 1990). There is a notable exception. Structural-reform programs eliminated the subsidies on chemical inputs in the late 1980s in many countries. Moreover, the 50% devaluation of the currency (CFA) of the French Economic Community in January 1994 further reduces the relative prices of organic to inorganic fertilizers. Where farmers have animal stocks, or can build them up, as in southern Mali, there have been increases in the manure production technology (covered compost heaps, cutting of millet and sorghum straw for the corrals), thus improving the quality and increasing the quantity of organic fertilizers from animals, household wastes, and crop residues. Again, these are extremely labour-intensive processes. The supply is limited by the size of the animal herds and the transformation technologies available, so there are limits to the substitution potential between organic and inorganic fertilizers (Sanders, 1994).

Researchers have been evaluating substitutes for inorganic fertilizer in semi-arid regions for at least 10 years. Further research to find low-cost complementary activities to inorganic fertilizer, and thereby reduce the costs to farmers, should not affec' the present development strategy. Inorganic fertilizer is a known technology with a substantial body of knowledge. It needs to be combined with increased water availability in the Sudanian region. Even higher returns are possible with the further addition of improved cereal cultivars for the Sudanian and Sahelo-Sudanian zones. Developing new cultivars for moderate inputs levels should be a higher-return activity than attempting to develop genetic tolerances to drought and low soil fertility at low or zero input levels under harsh conditions. Increasing farm-level yields and incomes without higher levels of input use may be impossible. The riskiness of fertilization alone is considerably reduced with increased water availability.

In the past, one principal constraint to fertilizer use was physical shortage. Government policy makers have typically put a low priority on fertilizer in their rationing of foreign exchange for imports. With the low priority given to fertilizer imports by governments, farmers often had to depend upon concessional imports from donors and upon irregular distribution systems. As sub-Saharan African countries adjust their overvalued exchange rates and remove import rationing by licensing and quotas, it will be easier for private or public distribution agencies to import fertilizer[1]. Achieving timely, low-cost delivery of fertilizer to farmers needs to be an important public concern. With the generally poor state of transportation infrastructure in most of sub-Saharan Africa, substantial public investments are required to assure the availability of fertilizers at the appropriate times and to facilitate the marketing of increased cereal yields.

Conclusions

Semi-arid, sub-Saharan Africa has often been identified as a land-surplus region with seasonal labour as the limiting constraint. This paper challenges this view and argues that in the semi-arid regions, the dual problems of low soil fertility and lack of water availability at critical times of crop development are the factors leading to poor yields. Once the soil fertility and water management conditions are improved, there will be a much larger impact from the introduction of a new cultivar. The failure to identify these principal constraints has had important implications for both research and development policies.

For some time, researchers and others have been claiming that a local input use, such as rock phosphate, a grain/legume rotation, crop residues, or the development of a low soil-fertility-tolerant cultivar would enable African governments to save foreign-exchange and the African farmers to avoid input purchases. Soil-fertility improvement is a critical requirement for crop yield increases in this region and the gains from inorganic fertilizer are well documented. Future research can reduce the long-run require-

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[1] There is a short run problem of the increasing price of inorganic fertilizer resulting from the elimination of fertilizer subsidies and from devaluation. However, devaluation also increases the price of imported food products relative to domestically produced food crops. This will increase the demand for domestic food crops increasing their prices. The relevant fertilizer price is then the cost of fertilizer relative to the domestically produced food price.

ments for inorganic fertilizers by finding more efficient utilization methods. Nevertheless, African farmers need to take advantage now of the yield increases possible with this input. More public and private investments supporting the fertilizer and seed industries are also expected to accelerate the development of those agricultural systems.

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Environnement Economique et Durabilité des Systèmes Agraires au Mali-sud, Mariage Difficile ?

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Résumé

L'agriculture au Mali-Sud est comme dans la plupart des pays au Sud du sahara caractérisée par une forte croissance démographique de l'ordre de 3% l'an que la croissance de la production agricole a du mal à atteindre. Des études récentes on montré qu'avec le niveau de rendement actuel, en Afrique, les surfaces cultivées devraient augmenter de 13% afin de maintenir une croissance de production céréalière de 4% l'an, susceptible de répondre aux besoins alimentaires de la population africaine (Mellor et Ramade, 1987 cités par IFDC/IFPRI, 1988, p. 8). Il s'est avéré que d'une manière générale, les rendements des céréales (mil/sorgho) n'ont pas évolué depuis une trentaine d'années au Mali (Bremen et Traoré, 1987) et les rendements de coton-graine accusent un tassement depuis 1975 et même une relative baisse en certains endroits du Mali-Sud (DRSPR, 1991). Des signes de dégradation des ressources naturelles sont constatés (Pieri, 1989, Van der Pol, 1990, 1991). Dans ce contexte, il est difficile d'envisager un accroissement de la production à travers une extension des surfaces cultivées.

L'utilisation des engrais organo-minéraux semble être une des alternatives en vue d'assurer une augmentation de la productivité de la terre et de la main d'oeuvre et d'éviter à terme une dégradation irréversible des ressources naturelles.

En zone Mali-Sud, de nombreuses technologies générées en station n'ont pu être adoptées par les agro-éleveurs puisque les conditions de leur élaboration sont différentes du vécu des exploitants. De plus, le risque climatique et économique fait qu'il n'est pas aisé pour les agriculteurs d'investir dans des intrants qu'ils ne sont pas sûrs de rentabiliser.

Des résultats de recherche attestent que les contraintes à l'accroissement de la productivité de la terre et de la main-d'oeuvre ne sont pas seulement d'ordre agrotechnique (Pieri, 1988) mais sont surtout liées à l'environnement socio-économique des exploitants et aux politiques mises en oeuvre.

C'est dans ce contexte que l'équipe système de production et gestion des ressources naturelles a développé depuis plus d'une decennie des approches méthodologiques combinées avec des technologies accessibles aux agro-éleveurs en vue d'assurer la durabilité des systèmes de production à base de coton. Ces approches prennent en compte différentes échelles (le terroir villageois, l'exploitation agricole et la parcelle). Dans la plupart des cas, il s'agit de combiner le savoir et le savoir-faire de l'exploitant du chercheur et du développeur ainsi que des technologies qui combinent des ressources auto-fournies (fumure organique) et importées (engrais par exemple) et assurer

une intégration de l'agriculture et de l'élevage. Le travail se fait en étroite collaboration avec les organismes de développement (CMDT notamment). Même à ce niveau, le poids de l'environnement macro-économique n'est pas sans conséquence sur l'adoption de certaines technologies notamment dans le domaine de la gestion des ressources naturelles.

Abstract

Like in most Sub-Saharan countries, agriculture in Southern Mali is characterized by a high population increase of about 3% per annum which the increase in agricultural population can hardly equal. Recent studies have shown that with the current yield level in Africa, cultivated areas should increase by 13% in order to maintain an annual cereal production growth of 4% that may meet the food requirements of the African population (Mellor and Ramade, 1987 quoted by IFDC/IFPRI, p8). It has been found that in general, cereal yields (millet/sorghum) have not evolved for some thirty years in Mali (Bremen and Traoré 1987) and grain cotton yields have been stagnating since 1975 and even declining in some locations of Southern Mali (DRSPR, 1991). Signs of degradation of natural resources can be observed (Pieri, 1989, Van der Pol 1990, 1991). In this context, it is difficult to forecast any increase in production through an expansion of the cultivated areas.
The use of organo-minerals appears to be one of the alternatives to achieve an increase in land and labour productivity and to avoid in the long run an irreversible degradation of natural resources.

In Southern Mali, many technologies developed on station could not be adopted by agro-pastoralists since the conditions under which they were generated are different from those experienced by farmers. Furthermore, the climatic and economic risk makes it hard for farmers to invest in inputs which they are not sure to make profitable.

Research results demonstrate that constraints to the increase in land and labour productivity are not only of an agro-technical nature (Pieri, 1988) but are mostly related to the socio-economic environment of farmers and to the policies enforced.

It is in this context that the farming systems and natural resources management team has developed for more than a decade methodological approaches combined with technologies accessible to agro-pastoralists in order to ensure the sustainability of cotton-based cropping systems. These approches take into account several scales (the village territory, the farm and the plot). In most cases, the objective is to combine the knowlege and know-how of the farmer, the researcher and the developer as well as technologies that associate self supplied (organic manure) and imported (fertilizers for example) resources and to integrate livestock and crop production. The work is carried out in close collaboration with development agences (particularly CMDT). Even at this level, the burden of the macro-economic environment is not without consequence on the adoption of some technologies, particularly in the area of natural resource management.

Introduction

La zone Mali-Sud est une zone à haut potentiel productif à l'échelle du pays. La culture cotonnière et son corollaire de traction animale introduite depuis le début des années 50 s'est traduite par un fort accroissement de la production agricole. Cette augmentation semble en grande partie liée à une extension des surfaces cultivées (80%) qu'à une amélioration du rendement de coton (20%) (CMDT[1], 1988). L'extension des surfaces cultivées, la forte croissance démographique et l'augmentation des effectifs animaux ont eu pour conséquences, une forte réduction des jachères et des zones de parcours avec en certains endroits, une amorce de la dégradation des ressources naturelles (Van der Pol 1991, Jansen et Diarra, 1990).

Si le succès du système coton ne peut s'expliquer par le seul accroissement des surfaces, il n'en demeure pas moins qu'en zone Mali-Sud, de nombreuses technologies générées en station n'ont pu être adoptées par les agro-éleveurs puisque les conditions de leur élaboration sont différentes du vécu des exploitants. De plus, le risque climatique et économique fait qu'il n'est pas aisé pour les agriculteurs d'investir dans des intrants dont ils ne sont pas sûrs de rentabiliser. Le relatif tassement du rendement coton-graine, le retour à un système de production extensif du maïs, la non-adoption de variétés améliorées de mil/sorgho et l'utilisation faible des produits vétérinaires confirment ce constat.

Des résultats de recherche attestent que les contraintes à l'accroissement de la productivité de la terre ne sont pas seulement d'ordre agrotechnique (Pieri, 1988) mais aussi liées à l'environnement socio-économique des exploitants et aux politiques mises en oeuvre.

Cet article tentera de faire une analyse critique des options techniques générées par la recherche en matière de préservation et d'amélioration des aptitudes productives de la terre et les conditions de transfert de ces technologies. Un accent particulier sera mis sur l'environnement économique des exploitants. Nous terminons par les expériences en cours au sein de l'équipe système de production et gestion des ressources naturelles (ESPGRN) en matière d'élaboration d'outils méthodologiques qui valorisent le savoir et le savoir-faire des exploitants agricole en vue de développer des systèmes de production durables et rentables dans l'environnement économique actuel du Mali-Sud.

Options Techniques

Les options techniques générées par la recherche concernent à la fois le coton, les productions céréalières et les animaux.

A) Succès du coton

La culture du coton est un exemple de la capacité paysanne d'adopter et d'intégrer des nouvelles technologies dans leurs systèmes de production. On peut citer entre autre, les variétés améliorées, des techniques culturales adaptées (notamment la traction animale, la fertilisation organo-minérale et une rotation avec les céréales sèches, etc...).

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[1] Compagnie Malienne pour le Développement des Textiles.

Le succès du système coton est en grande partie lié à une bonne adéquation entre recherche et développement par la génération et la diffusion des technologies et aussi l'organisation verticale de la filière (amont et aval). La CMDT de par son héritage des acquis institutionnels entre la CFDT[6] et l'IRCT[7] a toujours gardé des relations privilégiées avec la recherche (IER[8]) à la fois thématique et système. En effet, elle finance depuis un certain nombre d'années l'ensemble du programme de recherche en station sur le coton. Elle est par conséquent impliquée en grande partie, dans la réorientation de ce programme par rapport aux réalités du terrain (Bosc et al. 1990; p. 195). De plus, les relations institutionnelles avec la recherche-système qui datent depuis plus de dix ans ont permis aux systèmes de vulgarisation de mieux s'adapter aux réalités du terrain à travers un meilleur ciblage des messages techniques (typologie) et une valorisation de la formation des jeunes agriculteurs (conseil de gestion). En effet, la CMDT a aussi facilité la création des Association Villageoises; en premier lieu pour organiser la commercialisation du coton. C'est aussi une structure qui a favorisé et soutenu la formation des jeunes agriculteurs en Bamanan, lesquels ont fini par assurer la relève de l'encadrement de base dans la distribution du crédit, la diffusion des technologies, etc...

En matière de vulgarisation, la CMDT joue un rôle prépondérant au Mali-Sud. En effet, elle encadre le coton, les céréales, ainsi qu'en partie les bœufs de labour. Il est à noter aussi qu'il s'agit d'une filière où la CMDT assure l'approvisionnement des semences, des intrants sur crédit et la commercialisation. Le coton est la culture de rente la plus importante au Mali-Sud (100% de la production nationale) et en fait le "moteur" du développement rural.

En effet, la culture de coton est un exemple d'une adoption de nouvelles technologies. Pour le Mali-Sud, les rendements du coton sont passés de 139 kilos par hectare en 1961 à 874 kilo par hectare en 1972 (Lele, 1975). Les dernières années, ils accusent un tassement autour de 1300 kg/ha, avec une relative baisse par endroits (DRSPR, 1991).

La production totale du coton était de 6 000 tonnes en 1961. Elle est passée de 50 032 tonnes en 1973/74 à 247 000 tonnes en 1988/89 (Kleene et al., 1989). Elle vient de dépasser les 300 000 tonnes pendant la campagne 1992/1993.

Comme déjà mentionné, cet accroissement de la production est surtout lié à une extension des surfaces. Dans tous les cas, la logique extensive semble toujours dominer celle d'une intensification à base de consommations intermédiaires (engrais notamment) et des investissements dans la production de la fumure organique (Berckmoes et al., 1990). Les résultats de recherche attestent que pour la zone de Koutiala (coeur de la zone contonnière) les doses d'engrais recommandées par la CMDT sur le coton ne sont respectées qu'à 75% (Brons et al., 1994, Kébé et Brons, 1994). Deux hypothèses peuvent être avancées pour expliquer cette situation:

- le tassement du rendement coton depuis plus de quinze ans et le prix fixe du coton-graine (85 FCFA/Kg pour le coton de premier choix de 1985 à 1994) peuvent amener

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[6] Compagnie Française pour le Développement des Textiles.
[7] Institut de Recherche sur le Coton et les Textiles.
[8] Institut d'Economie Rurale.

les agro-éleveurs à réduire les quantités d'engrais minéraux apportées ;

- il est aussi probable, que du fait de la production importante de fumure organique (environ 30 tonnes/exploitation en culture attelée avancée et par an), les agro-éleveurs décident de substituer partiellement cette fumure organique àl'engrais acheté.

B) Les productions céréalières

Les céréales sont cultivées en rotation avec le coton. Les productions céréalières en zone Mali-Sud ont d'un point de vue technique, connu une dualité en matière de génération et d'adoption technologique. Les mils/sorgho qui constituent la base de l'alimentation n'ont pas connu d'amélioration du moins au niveau paysan alors que les variétés améliorées de maïs ont été vulgarisées et largement adoptées au début des années 80.

Il s'est avéré que d'une manière générale, les rendements des céréales (mil/sorgho) n'ont pas évolué depuis une trentaine d'années au Mali (Breman et Traoré, 1987). Au Mali-Sud, de par leur position dans la rotation, ils bénéficient des arrières effets des intrants apportés sur le contonnier. Cependant, ces arrières effets ne semblent pas compenser les exportations et ces deux spéculations sont aujourd'hui considérées comme les plus dégradantes. Van der Pol (1991) montre que plus de 40 % du revenu paysan au Mali-Sud proviendrait d'activités susceptibles d'entraîner la dégradation des sols.

Contrairement au mil/sorgho, le maïs a connu un net progrès au début des années 80 (introduction de variétés améliorées, utilisation croissante d'engrais minéraux). Cette situation de faveur, a permis un fort accroissement de l'offre en maïs. Elle est rendue possible grâce à un environnement économique incitatif par la fourniture d'intrants à crédit et la commercialisation du surplus avec des prix au producteur connu avant le début de la campagne. Cette situation a changé avec la mise en oeuvre des politiques d'ajustement structurel et le maïs est de nouveau cultivé surtout pour l'auto-consommation.

C) L'intégration agriculture élevage

L'introduction de la traction animale a permis aux agro-éleveurs du Mali-Sud de constituer un noyau d'élevage et se familiariser avec les techniques de gestion du troupeau qui jadis étaient assurées par les Peulhs. De plus, dans le souci d'une meilleure sécurisation des revenus-coton, les exploitants ont capitalisé dans l'élevage (bovin notamment). Dans le souci d'une meilleure gestion du troupeau associé à l'exploitation agricole, la recherche a développé des techniques de production et de conservation des fourrages cultivés et des parcs améliorés qui favorisent la production de fumure organique. Les cultures fourragères comme le niébé sont vulgarisées et même adoptées par les exploitants; toutefois, la difficulté se situe au niveau du calendrier agricole. En effet, la période de récolte dite optimale du niébé coïncide avec la récolte du maïs et les premières récoltes du coton.

La dolique cultivée en association avec le maïs en vue de nourrir les boeufs de labour pose beaucoup moins de problèmes au niveau du calendrier agricole. Quand aux cultures fourragères produites à partir de jachères de courte durée, les expérimentations en milieu paysan montrent une forte adaptabilité des espèces telles que le *Stylosanthes hamata* qui a donné un rendement trois fois meilleur que celui du niébé. La différence à ce niveau cependant est le problème de protection des parcelles dites fourragères qui sont situées dans des zones à gestion communautaire peu économiquement rentable ou incitatives à l'investissement (semences, fil de fer barbelé).

L'Environnement Economique.

A) La modélisation

Actuellement, les intrants sont essentiellement utilisés sur le coton : engrais (80%), insecticides (100%), herbicides (80%) fumure organique (90%). Le reste des intrants est utilisé sur le maïs (ESPGRN, 1994, Brons et al., 1994). Dans les conditions actuelles, la situation du maïs est différente de celle du sorgho et petit mil, vu que le maïs a une forte réponse aux engrais.

Les résultats d'une modélisation mathématique[9] sur quelques scénarios basés sur des mesures proposées par la recherche, montrent le poids de l'environnement économique. Il s'agit notamment de l'utilisation de l'engrais minéral sur les céréales en combinaison avec l'utilisation des variétés améliorées (Kébé, 1993).

Une des hypothèses testées est que le rendement actuel du sorgho/mil et l'environnement économique ne sont pas de nature à inciter les agro-éleveurs à utiliser les intrants minéraux sur ces spéculations. Ce manque d'apport en intrants est considéré comme une des causes du bilan négatif des nutrients (Van der Pol, 1991). Les résultats montrent que dès que l'environnement économique le permet, le comportement des exploitants du Mali-Sud est identique à ce qu'on peut observer ailleurs. Ils investissent dans les intrants pour améliorer la productivité de la terre à condition que ces investissements soient rentables. Ainsi, la possibilité d'accroître la production agricole grâce à des consommations intermédiaires d'origine industrielle ne peut se réaliser que si l'on accepte l'amélioration du prix d'achat au producteur par rapport au prix des produits industriels.

La contrainte des ressources rares (notamment la contrainte de liquidité) semble jouer un rôle très important dans l'évolution des systèmes et le choix des spéculations productives (Boussard, 1990 ; Ruttan et Hayami, 1990 ; Benoit-Cattin et Kébé, 1992). La deuxième hypothèse testée est un approvisionnement en intrants dans les mêmes conditions que le coton, pour faire des investissements dans des intrants destinés à des variétés améliorées de maïs. Cela toutefois suppose une disponibilité en liquidité ou l'accès au crédit.

Les résultats obtenus montrent en effet que les investissements en intrants deviennent très importants quand il y a accès au crédit, comme un emprunt à court terme avec un taux d'intérêt de 25%. Mais ces résultats restent conditionnés à une relative garantie des débouchés.

[9] Les détails des modèles peuvent être trouvés chez Benoit-Cattin et al. 1991, Kébé, 1993.

Pour le coton, une augmentation sensible de l'offre semble avoir très peu (ou pas) d'effet sur le prix au producteur, étant donné que ce prix est fixé d'avance et qu'il y a une certaine garantie d'achat des quantités produites. Par contre, au niveau des céréales qui sont laissées au jeu du marché, il est très probable qu'une augmentation importante de l'offre aura nécessairement des conséquences sur le prix, à moins, que les paysans trouvent d'autres débouchés pour écouler le surplus.

B) Ajustement structurel et ses conséquences sur les systèmes de production au Mali-Sud

Les résultats de la modélisation ont été confirmés par les enquêtes auprès des paysans (ESPGRN, 1994) ainsi que par les effets de l'ajustement structurel. Les mesures d'ajustement structurel, en place depuis le début des années 80, se sont traduites par une suppression des subventions des intrants agricoles et par la libéralisation du marché des céréales sèches.

L'exemple le plus illustratif des effets des mesures macro-économiques est la culture intensive du maïs du début des années 80. Suite à la sécurisation de la commercialisation du surplus et la disponibilité des intrants au crédit pour le maïs par l'état, le système de production a changé. L'effet était l'accroissement de production de maïs suite à une intensification à base de consommations intermédiaires (variétés améliorées, engrais) et une culture en pure. En certains endroits, la culture du maïs avait commencé à concurrencer en superficies celle du coton (Raymond *et al.*, 1990). Au début des années 80, les rendements en maïs ont pu atteindre 2 000 voire 3 500 kg/ha en milieu paysan. Vers 1986, l'état s'est désengagé de l'octroi du "crédit-intrants" et de la commercialisation. Face à cette situation, la production s'est ralentie par une diminution des surfaces en culture pure du maïs, un retour aux pratiques de cultures associées, avec peu ou pas d'apport d'intrants. (Raymond et al., 1990; Kébé, 1993; Bourhton et Témé, cités par Kamara *et al.*, 1994). Actuellement, les rendements moyens dépassent rarement 1 500 kg/ha (Brons *et al.*, 1994).

En dehors de la suppression des subventions pour l'ensemble des intrants, le coton bénéficie toujours des prix administrés connus avant le démarrage de la campagne. La garantie de la commercialisation fait que la CMDT jusqu'à présent assure l'approvisionnement en intrants à crédit sans frais financiers. La distribution des intrants à l'échelle du village est assurée par les associations villageoises (AV) qui sont aussi responsables de la commercialisation primaire en rapport avec la CMDT, la BNDA et les privés.

L'environnement économique des producteurs de coton semble relativement plus incitatif à cause de l'accès aux intrants et la garantie de la commercialisation des coton-graines. Cependant, l'évolution du rapport des prix relatifs "input/output" ne semble pas favorable aux producteurs (Kébé, 1989, Bosc et al. 1990 pp. 196-197). Cette situation expliquerait sans doute la réduction des apports d'intrants (engrais notamment) dans des zones à forte expérience ou dominance en culture cotonnière.

Le récent changement de parité du FCFA n'est certainement pas aussi sans conséquence sur les systèmes de production au Mali-Sud (augmentation du prix des intrants importés, du prix du coton-graine et de la relance de l'exportation du bétail vers la

Côte d'Ivoire). Tous ces changements posent le problème de l'anticipation pour l'agro-éleveur en vue de maximiser le profit de ses investissements.

Les résultats du suivi-évaluation permanent de 1994, montrent que la dévaluation n'a pas affecté l'apport d'intrants sur le coton tandis que les quantités apportées sur le maïs ont été réduites de façon significative (notamment à Kadiolo) (ESPGRN, 1995). Dans tous les cas, les quantités apportées n'atteignent pas les doses recommandées. Il est probable que l'augmentation du prix de coton-graine de l'ordre 47 % ait incité les agro-éleveurs à maintenir leur niveau d'investissement. Certains paysans au moment de la restitution des résultats déclarent vouloir augmenter leur superficie en coton cette année.

La dévaluation du FCFA semble en outre créer des opportunités nouvelles pour l'ensemble des productions animales. Il est à noter que la zone Mali-Sud est devenue la première zone d'élevage depuis 1985, suite à la capitalisation des agriculteurs et à la sédentarisation des peulhs. Si les organisations paysannes arrivent à s'approprier des retombées de cette apportunité, il est probable qu'à terme, elles puissent changer de mode de conduite en investissant davantage dans lesdites productions. Une des conséquences de la modification du système de gestion des espaces agro-pastoraux pourrait être l'augmentation de la disponibilité en fumure organique qui constitue un intrant essentiel pour le maintien et la restauration de la fertilité des sols.

C) L'aversion au risque des producteurs

L'aléa d'ordre climatique et économique font que les agriculteurs n'acceptent pas facilement investir dans des activités dont ils ne sont pas sûrs de rentabiliser. En effet, peut-on considérer comme durable et sans risque, le fait d'augmenter les rendements de façon substantielle en bonne année mais qui s'effondrent lorsque la pluviométrie devient défavorable ? De même, est-il envisageable pour un exploitant qui pour des contraintes de liquidité est obligé de brader sa production céréalière en période de récolte et dans certains cas, de les racheter à deux voire trois fois plus cher quelques mois plus tard, de faire des anticipations ? La minimisation des risques est avant tout une condition primordiale à l'investissement par les paysans.

On comprend dès lors, la complexité des sytèmes de production en place. Elle est liée au fait que les exploitants poursuivent en général plusieurs objectifs : sécurité alimentaire et recherche de grain monétaires. D'où la recherche d'une relative complémentarité entre cultures de rente (coton, éventuellement maïs et arachide) et cultures vivrières. Les interventions de la CMDT dans l'approvisionnement des intrants et la commercialisation des produits agricoles assurent aux paysans une source relativement certaine des intrants et un débouché sûr pour le coton. Les céréales profitent des arrières-effets des intrants apportés sur le coton, bien que la stratégie paysanne en vue de minimiser les risques économiques et climatiques, consiste à moins investir dans des consommations intermédiaires d'origine industrielle (ESPGRN, 1994). Des études ont montré qu'en termes de résultat, les zones de production cotonnière sont celles qui dégagent le plus gros surplus céréalier (Dioné, 1989 ; CMDT 1992, 1993). Il y a un bon niveau moyen d'auto-fourniture en céréales dans les zones cotonnières (Kébé et Brons., 1994).

Nouvelles Politiques Agricoles et Problèmes de Transfert de Technologies

Le système d'encadrement mis en place par la CMDT a permis de façon progressive, de mieux responsabiliser les jeunes alphabétisés qui assurent le relais en matière de suivi des exploitations, de distribution des intrants et de commercialisation du coton-graine. Les AV, malgré le rôle important qu'elles jouent dans la filière coton, traversent une période de crise liée surtout à des problèmes de gestion. En même temps, il est de plus en plus question du retrait de l'encadrement classique CMDT et la poursuite de la création des zones d'animaux et d'expansion rurale (ZAER) qui semblent mieux cadrer avec la politique de décentralisation et le désengagement de l'état.

Cette situation nécessite que des réflexions soient menées en matière de transfert des technologies. En effet, les paysans, sont de plus en plus dans l'obligation de chercher eux-mêmes une partie des conseils techniques dans un système dans lequel l'AV et les néo-alphabétisés jouent un rôle important.

Le désengagement de la CMDT dans le crédit rural est une option retenue dans le nouveau contrat-plan Etat-CMDT-Producteurs de coton. Ce désengagement doit semble t-il se faire de façon progressive avec des mesures d'accompagnement. Le relais doit être assuré par les banques de la place (BNDA notamment), les caisses mutuelles (Kafo Jiginew) et les organisations paysannes en rapport avec les privés. A l'heure actuelle, tous les paysans, dans les villages les plus petits et les plus éloignés ont accès aux intrants sur crédit au même prix. La question qui mériterait d'être posée est de savoir si le désengagement de la CMDT n'aura pas pour conséquence une augmentation du prix des intrants qui en retour pénaliserait, compte tenu de l'éloignement des zones de productions, les activités à forte consommations intermédiaires.

A) Discussions

A1) Est-il possible d'améliorer l'environnement économique ?

D'un point de vue institutionnel, certaines expériences en cours méritent d'être suivies. Avec la création de la mutuelle des paysans (Kafo Jiginew) en rapport avec le PRMC[10], des expériences de crédit à la commercialisation des céréales et de recherche de marchés aussi bien au niveau national que régional sont en cours. L'institutionnalisation d'un tel système permettra sans doute de minimiser les risques et de faire des anticipations.

Grâce à cette anticipation, on peut espérer une meilleure implication des organisations paysannes dans la gestion du crédit et la recherche de débouchés pour les différentes productions. Cette anticipation pourrait aussi contribuer à créer un climat de confiance au niveau des exploitants et partant améliorer les revenus et favoriser les investissements dans le capital "sol".

[10] Programme de Restructuration du Marché Céréalier.

A2) Quel rôle à envisager pour la recherche-système ?

La recherche-système cherche à aider les paysans en vue d'une amélioration de la productivité et de la durabilité de leurs systèmes de production à partir des données de l'environnement socio-économique en place. Les objectifs de production, les stratégies comme la diminution des risques ainsi que la diversité entre les exploitations sont à prendre en compte. C'est dans ce cadre, que l'ESPGRN développe des techniques et des approches en vue d'une meilleure combinaison des ressources et des approches en vue d'une meilleure combinaison des ressources auto-fournies (fumure organique, fourrages, etc.) et celles achetées (engrais, aliment de bétail) en vue d'une meilleure gestion des aptitudes productives de la terre, et une exploitation durable des systèmes de production. La durabilité des systèmes de production va de pair avec la productivité. Pour cela, un accent est mis sur le maïs. Le *Striga* est un autre point d'attention, vu son effet négatif sur les céréales. L'augmentation de la productivité des boeufs de labour, notamment à travers l'alimentation est un autre domaine important.

Un accent est mis sur l'élaboration d'outils méthodologiques qui permettent de mieux impliquer les paysans dans toutes les phases de la recherche (diagnostic/planification ; expérimentation et évaluation). On peut citer le développement des méthodes participatives qui permettent la prise en compte des critères paysans par rapport aux variétés des céréales, comme le maïs et leur opinion sur les variétés améliorées proposées par la recherche. Il en est de même pour la lutte contre le *Striga*.

Depuis 1993, l'ESPGRN est en train de développer et de perfectionner une méthodologie simple de diagnostic/planification relative à la gestion de la fertilité des sols. L'outil doit permettre aux exploitants en collaboration avec l'encadrement (1) d'appréhender l'état actuel et d'analyser les contraintes de la gestion de fertilité des sols au niveau du village et de l'exploitation et (2) de raisonner des décisions à prendre et des actions à entamer en matière de gestion de fertilité des sols en tenant compte des éléments structurels des exploitations et de l'économie rurale (ESPGRN, 1994).

Dans le même sens, l'ESPGRN est aussi en train de développer un outil de gestion permettant de faciliter l'intégration des activités d'élevage dans celles de l'exploitation et de conseiller aux propriétaires du bétail de mieux gérer leur noyaux d'élevage. Cette gestion devrait prendre en compte la taille du cheptel, les objectifs du paysan, la disponibilité de fourrage, la capacité d'achat des intrants et les possibilités de culture fourragère. Le travail se fait en étroite collaboration avec les paysans des villages concernés et les organismes de développement (CMDT notamment).

L'échelle des exploitations agricoles et des systèmes agraires villageois, un axe de recherche qui fait la jonction avec le programme économie des filières de l'IER vient de voir le jour. Les thèmes retenus sont entre autres, la dévaluation, et les systèmes financiers ruraux dans un contexte de désengagement prévu de la CMDT du crédit agricole.

Conclusion

D'un point de vue agro-technique, ce sont surtout les cultures céréalières (mil/sorgho) qui accentuent la dégradation des sols. En effet, les arrières effets des intrants apportés sur le coton en tête de rotation ne semblent pas compenser les exportations. Le défi de la recherche est de trouver des variétés nouvelles adaptées aux contraintes climatiques à forte réponse aux intrants qui se substitueraient à la terre et qui intègrent les critères et objectifs de production des agro-éleveurs.

De telles variétés n'ont de chance d'être adoptées par les agriculteurs que lorsque l'environnement économique est suffisamment incitatif. Le désengagement de l'état dans la commercialisation des céréales fait que le risque économique est devenu plus important et ce faisant ne permet plus aux exploitants de faire des investissements productifs.

Cet article a montré que le transfert des technologies qui demandent un investissement en argent, requiert une amélioration du rapport des prix ('inputs/output'). Il est probable que suite à la dévaluation, ces conditions soient améliorées pour l'élevage, mais l'effet n'est pas encore visible pour les céréales.
L'investissement dans la production de la fumure organique demande plus de main-d'oeuvre; même dans ce cas, la rentabilité du coton est une source importante de motivation. De plus, le poids de l'environnement macro-économique n'est pas sans conséquences sur l'adoption de certaines technologies notamment dans le domaine de la gestion des ressources naturelles. La plupart des technologies proposées ne donnent des résultats qu'à moyen et long terme (technique de lutte anti-érosive et de gestion de terroir villageois).

D'un point de vue technique, il ne semble pas aisé non plus, de quantifier les effets, même à moyen terme. Cette situation pose le problème de la prise en charge des coûts de la durabilité économique. Ce problème se pose aussi par rapport aux réflexions sur une utilisation éventuelle des mesures incitatives dans ce domaine particulier en vue d'accélérer l'adoption de certaines technologies.

Les approches méthodologiques et/ou les techniques développées ou en cours de développement au sein de l'ESPGRN cherchent à combiner ressources auto-fournies et celles achetées en vue de minimiser les effets négatifs du climat et des mesures macro-économiques. L'intégration des approches participatives au sein des équipes thématiques permettront à la recherche d'intégrer les préoccupations paysannes au niveau de la génération des technologies et par conséquent augmenter les chances de succès en matière d'adoption.

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Le Conseil de Gestion à l'Exploitation Agricole Comme Nouvelle Option dans le Système de Vulgarisation en zone Cotonnière du "Burkina Faso"

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Résumé

Le conseil de gestion est une méthode de transfert de technologies qui s'adresse dans un premier temps à des producteurs alphabétisés et/ou scolarisés, qui se réunissent tous les 15 jours en salle. Ces rencontres dites séances conseil de gestion sont des cadres de formation et d'analyse des résultats d'exploitation, et des lieux de proposition de solutions techniques et économiques aux problèmes rencontrés. Elles sont animées par les agents de vulgarisation agricole. Cette analyse est conduite en groupe en s'appuyant sur des cas individuels et à partir des données qualitatives et quantitatives collectées sur l'exploitation par les participants alphabétisés et/ou scolarisés. Un ensemble de fiches regroupant plusieurs tableaux traitant de tous les aspects de production de l'exploitation sert de support à la collecte et l'exploitation des données.

Ces échanges donnent lieu à des discussions sur les différentes contraintes, les difficultés rencontrées et les moyens à mettre en oeuvre pour y remédier. Ils visent l'amélioration des productions agricole et animale, et donc peuvent porter sur une gamme diversifiée de thèmes comme : les techniques culturales, les techniques de production et d'utilisation de la fumure organique (d'origine animale ou d'autres sources), les techniques de conservation des eaux et du sol (aménagement des champs cultivés), la protection phytosanitaire, l'introduction de nouvelles spéculations (riz pluvial...). A tous ces thèmes techniques, l'adhésion est volontaire... Les actions techniques sont conduites par les producteurs sous leur propre gestion. Ils doivent alors jouer un rôle très important dans la diffusion des innovations et autres informations techniques et socio-économiques à travers l'organisation de visites commentées au niveau du village.
Il est évident que dans ce cadre, une attention particulière est donnée à la production céréalière pour les besoins d'auto-consommation et de commercialisation.

Abstract

The management council is a technology transfer method primarily designed for literate and/or educated producers who meet in session every 15 days. These meetings called management council sessions are frameworks for training and farm results analysis as well as venues for proposing technical and economic solutions to the problems encountered. They are monitored by agricultural extension workers. This analysis is conducted in group and is based on individual cases and qualitative and quantitative data collected on the farm by the literate and/or educated participants. A set of forms

with several tables on all aspects of the farm production is used as a support to the collection and processing of data.

These exchanges give rise to discussions on the various constraints, the difficulties encountered and the means to solve them. Their objectives are to improve agricultural and animal productions. Consequently they may deal with wide range of topics such as: cropping techniques, organic manure production and utilization techniques (manure from animals or other sources), water and soil conservation techniques (cultivate fields management), phytosanitary protection, introduction of new crops (rainfed rice....). For all these technical themes, adherence is on a voluntary basis. The technical actions are conducted by producers under their own management and are technically and economically evaluated in group. Producers must therefore play an important role in the dissemination of innovations and other technical and socio-economic informations through the organization of commented visits at village level. It is obvious that in this context, special attention is given to cereal production for self consumption and marketing requirements.

Introduction

Dans la zone cotonnière du Burkina Faso, les systèmes de production ont connu une importante évolution ces vingt dernières années. Grâce à la culture du coton, le niveau d'équipement s'est considérablement développé et la consommation en intrants est devenue plus importante.

Face à cette situation, le système de vulgarisation agricole qui est resté basé sur la simple diffusion des informations (thèmes) techniques ne répond plus aux attentes des producteurs.

En effet, les producteurs de la zone sont de plus en plus confrontés à des problèmes de gestion technique et économique nouveau, pour la solution desquels ils ne sont nullement préparés. Pour n'en citer que quelques-uns, on a:

- la baisse de la fertilité des sols conduisant à une baisse des rendements en coton graine;
- les prix très fluctuant des intrants agricoles aggravés par la dévaluation du franc CFA;
- le désengagement des organismes de crédit pour le crédit moyen terme (crédit équipement) pour se limiter au crédit d'intrants consommables (annuel).

C'est de ce constat qu'est née la nécessité de trouver une autre forme d'animation en milieu paysan qui permette un meilleur transfert des connaissances techniques et une plus grande prise en compte de l'environnement économique dans la gestion des systèmes de production.

Le conseil de gestion (CdG) se veut donc d'être un outil d'aide à l'analyse/diagnostic des situations individuelles des exploitations, outil d'appui et d'aide à la prise de décision, dont l'exercice se fait en groupe.

Cadre institutionnel

Dans l'expérience du Burkina Faso, la mise en oeuvre du conseil de gestion s'est faite au sein d'un programme de Recherche-Développement liant un organisme de développement, deux organismes de recherche et une structure de vulgarisation, à savoir :

- le Projet de développement rural intégré des provinces du Houet, de la Kossi et du Mouhoun (PDRI/HKM);
- l'Institut d'études et recherches agricoles, programme recherche sur les systèmes de production (INERA/RSP);
- le Centre international en recherches agronomiques pour le développement (CIRAD);
- le Centre régionale de promotion agro-pastorale, cellule formation technique continue (CRPA/FTC).

Une carte jointe en annexe situe la zone d'activité de mise au point du conseil de gestion par le programme R-D avec les villages sites.

Méthodologie

La méthode du conseil de gestion a été introduite en Afrique de l'Ouest d'abord au Sénégal au début des années 1970, puis au Mali-Sud à partir de 1982. C'est dans ce pays voisin du Burkina Faso que le conseil de gestion a été défini comme; "'une méthode qui prend en compte l'ensemble de la situation d'une exploitation et cherche en dialogue avec le paysan, un cheminement d'amélioration qui s'étend souvent sur plusieurs années" (Kleene et Kone , 1988).

Appliquée au Burkina Faso, la démarche "conseil de gestion aux exploitations agricoles" vise à définir, à partir d'une analyse du système de production actuel (diagnostic sur les aspects techniques, économique et social), en collaboration avec les producteurs eux-mêmes, un système de production mieux adapté et durable. Cette démarche demande beaucoup de souplesse dans la définition des actions à entreprendre et surtout une forte implication des producteurs à toutes les étapes du processus; elle se doit d'être une démarche participative.

Dans l'expérience burkinabè, la démarche s'adresse dans un premier temps à des exploitations comprenant un scolarisé en français ou un alphabétisé en langue Dioula, capable de prendre des notes qualitatives et quantitatives sur son exploitation.

Ces producteurs se rencontrent tous les 15 jours en salle lors des 'séances conseil de gestion' animées par un ou plusieurs agents de vulgarisation. De ce fait, les premiers interlocuteurs sont forcément un groupe restreint de producteurs, mais qui peuvent et acceptent de jouer un rôle dans la diffusion d'informations et d'innovations techniques au niveau du village (extension aux non-alphabétisés), l'objectif étant d'atteindre l'ensemble des producteurs. La mise en oeuvre du conseil de gestion comporte plusieurs étapes, qui sont:

- le choix des participants;
- les séances conseil de gestion;
- la mise en place d'innovations visant la résolution de certains problèmes de production au niveau de l'exploitation;
- l'extension des acquis de la démarche aux autres producteurs par les visites commentées, les séances élargies aux autres producteurs et l'animation de groupe menée par les 'paysans animateurs' dans leurs quartiers respectifs.

A) Choix des participants

Des séances d'information et de sensibilisation ont été organisées au niveau des différents villages-cibles, conjointement par la recherche et les structures d'encadrement. Lors de ces séances, sont expliquées la philosophie du conseil de gestion en mettant en évidence la nécessité d'une inscription volontaire et la disponibilité à jouer le rôle d'animateur. On procède par la suite à un recensement des alphabétisés et/ou scolarisés résidant dans le village et ses environs. Des séances de discussions permettent une inscription volontaire à concurrence d'un noyau de 20 à 30 producteurs par village. Il est important de s'assurer d'un niveau de scolarisation ou d'alphabétisation suffisant.

B) Les séances conseil de gestion

Les séances conseil de gestion se tiennent une fois tous les quinze jours. Les groupes de producteurs décident d'un commun accord et suivant leur convenance, le jour de la tenue des séances.
Les séances en salle portent sur:

- des éléments de formation où sont apprises des notions nécessaires à l'expression et à l'analyse des résultats techniques et économiques de l'exploitation (concepts, terminologies, méthodes de calcul,...);
- des éléments d'information sur les techniques pratiquées par les producteurs et/ou sur les innovations en relation avec un diagnostic au cas par cas;
- des discussions permettant d'établir un diagnostic sur des situations concrètes;
- des discussions permettant de proposer des actions techniques concrètes pouvant intéresser aussi bien les exploitations considérées en exemple que toutes les autres qui connaissent des problèmes similaires (intérêt de l'innovation, évaluation technico-économique, ...);
- des discussions pratiques sur la mise en oeuvre des actions techniques (aspects logistiques surtout).

Le déroulement d'une séance peut se résumer ainsi :

- Premièrement, pour une fiche donnée du carnet conseil de gestion, deux ou trois cas différents sont choisis parmi les participants. Ils sont portés au tableau noir devant tout le monde. Cet exercice permet de comprendre comment remplir la fiche (type de renseignements demandés, calculs à effectuer, etc.);
- deuxièmement, une discussion de groupe est engagée sur les cas exposés. La variabilité des situations permet d'alimenter la discussion. Ces discussions permettent d'échanger entre le ou les animateurs et le groupe: l'animateur apportant des informations techniques ou économiques et le groupe cherchant à bien les placer dans les situations choisies. Ainsi, le diagnostic ne sera plus le fruit du seul animateur, mais le résultat d'une réflexion menée en groupe;
- troisièmement, la discussion débouche sur l'identification de solutions concrètes, adaptées à ces cas individuels. Chacun des participants cherche alors à s'identifier par rapport à l'un des cas traités. Il apparaît alors la nécessité de disposer d'un panel d'innovations à proposer et à adapter aux besoins et aux moyens de chacun.

- quatrièmement, des listes de volontaires sont établies pour un certain nombre d'actions techniques et les problèmes de logistiques sont abordés.

A partir de l'analyse menée en groupe, on essaie de faire ressortir les points essentiels pour une prise de décision. On intègre la variabilité des situations, mais la décision finale revient à chaque paysan. Pour ce faire, il doit se reconnaître par rapport aux différents exemples traités en groupe, ou alors relancer le débat sur son cas particulier. En résumé, l'analyse de groupe donne un fil pour une analyse et une décision individuelles.

C) Les innovations techniques

L'amélioration du fonctionnement de l'exploitation est la finalité recherchée par l'approche conseil à travers tout cet important travail d'analyse/diagnostic. Il s'agit d'identifier et de mettre en place, en relation avec les contraintes dégagées, des innovations pour améliorer les résultats techniques et économiques de l'exploitation. Ce point se trouve être le plus intéressant pour les producteurs. Cet ensemble d'innovations, qui évoluent d'une année àl'autre, est le résultat d'une démarche recherche-action menée conjointement entre la recherche, le développement et les paysans en Conseil de Gestion. Elles peuvent toucher des domaines aussi variés que : l'aménagement des exploitations, la gestion de la fertilité des sols, l'intensification et la diversification des systèmes de culture, l'intégration agriculture - élevage, etc...

L'aménagement des parcelles cultivées: Ce volet regroupe un ensemble d'innovations visant à fixer les parcellaires dans le temps et dans l'espace en vue de lutter efficacement contre les phénomènes d'érosion et de développer des stratégies de restauration de la fertilité des sols. Ce sont notamment:

- des plantations de haies-vives anti-érosives ou de haies impénétrables pour lutter contre la divagation des animaux.
- la création de bandes enherbées, naturelles ou ensemencées en Andropogon pour lutter contre l'érosion.
- la plantation d'arbres ou haies d'alignement pour la délimitation du foncier.

L'intrégration agriculture / élevage: Dans ce cadre on s'intéresse notamment au crédit à l'équipement, la production de fourrages cultivés (dolique, Stylosanthes, sorgho fourrager), le stockage des résidus de récolte, la complémentation des animaux de trait en fin de saison sèche, la mise en place d'étables et fosses fumières, l'amélioration de la production de fumier par l'utilisation de litière.

L'intensification/diversification des systèmes de culture: On intègre dans ce domaine, l'amélioration du travail du sol avec l'introduction du scarifiage du sol en sec (matériel et technique) en association avec la complémentation des animaux de trait, suivi de labour, l'utilisation de la fumure organique, l'introduction du riz pluvial, le sarclage au mono-boeuf, et le buttage tardif au mono-boeuf. L'introduction des nouvelles techniques de protection phytosanitaire du cotonier demande une formation intense des producteurs.

Il est évident que cette série d'innovations ne peut pas être mise en place systématiquement à l'échelle d'une même exploitation au même instant. Cependant, leur connaissance et la relation que le producteur a établie avec son système de production lui permet d'opter volontairement pour plusieurs d'entre elles, selon une hiérarchisation personnelle ou la disponibilité des moyens d'action. Par ailleurs, le producteur en CdG doit pouvoir définir un profil d'évolution de son exploitation selon ses propres objectifs, intégrant certaines innovations parmi celles proposées.

D) L'extension aux non alphabétisés

La démarche 'Conseil de Gestion' s'appui fortement sur un noyau de producteurs alphabétisés avec lequel est conduit tout le travail d'analyse/diagnostic et de réalisations techniques, et essaye dans une seconde phase, d'étendre ces acquis à l'ensemble des producteurs. Elle compte de ce fait sur la responsabilisation de ce noyau de producteurs vis-à-vis des autres, en terme d'animation et d'échanges. Pour ce faire, les méthodes d'approche suivantes sont utilisées :

- les visites commentées
- les séances CdG élargies
- la formation des paysans animateurs.

D1) Les visites commentées

Ce sont des rencontres ponctuelles organisées par les producteurs en Conseil de Gestion autour des thèmes techniques mise en place et bien menés. Elles sont organisées àl'intention des producteurs non participants au CdG du village ou des villages voisins.

Au cours de ces visites, les réalisations techniques sont présentées aux participants depuis le diagnostic jusqu'à la mise en place par le producteurs pour faire ressortir les problèmes saillants autour du thème général et de la réalisation, en particulier. Les autres producteurs participants au CdG contribuent pour donner davantage de renseignements.

Au cours de ces visites, les conseillers agricoles assistent en observateurs et peuvent intervenir pour donner des informations techniques complémentaires à celles des producteurs. Ce genre de visites vont de paire avec l'animation de groupe menée dans les quartiers par les paysans animateurs.

Cette logique va avec l'analyse faite par Mercoiret *et al.* (1994) qui considèrent que, 'la réunion de groupe reste un outil efficace dès lors qu'elle est axée sur des thèmes précis correspondants au besoins des producteurs, et qu'elle combine des aspects de démonstration et de discussion réelles dans lesquelles les paysans peuvent exprimer librement leur point de vue'.

L'option de ces visites commentées est de faire connaître des innovations aux autres producteurs, de leur donner l'information technique, d'inciter à l'adoption. Selon toujours Mercoiret *et al.* (1994), les paysans sont davantage convaincus par ce qu'ils voient chez les autres producteurs que les 'discours' d'un encadreur.

D2) Les séances CdG élargies

Des séances Conseil de Gestion spéciales sont organisées de temps en temps, à l'intention des chefs d'exploitation (non alphabétisés), des notables de quartier et autres leaders d'opinion. Elles permettent de faire connaître à l'ensemble du village des travaux qui sont conduits par le groupe en CdG, de mieux cerner les besoins d'un ensemble plus vaste de paysans. Elles offrent l'occasion de faire des restitutions sur l'évaluation faite en séance CdG sur certaines innovations techniques, et donc de définir les modalités de leur diffusion.

D3) Les paysans animateurs

Si les visites commentées et les séances CdG élargies permettent de faire connaître les actions techniques aux autres producteurs, elles restent tout de même d'efficacité limitée. Pourtant, les non-participants au conseil de gestion s'intéressent aux actions techniques, participent aux visites commentées, et sollicitent d'être suivis.
Aussi, elles doivent être complétées par une animation conduite par les participants CdG au sein des différents quartiers et groupes de producteurs. Ces animations portent sur certaines notions de gestion de l'exploitation agricole comme les rendements, les itinéraires techniques, les analyses de marge brute, etc... Elles doivent aussi porter sur la diffusion des innovations techniques au niveau des exploitations en s'appuyant sur les fiches techniques élaborées en langue nationale dioula et mises à leur disposition. On part de l'hypothèse qu'eux-mêmes puissent faire évoluer leurs exploitations de manière à se servir de certaines réalisations concrètes comme base de discussion avec le groupe.

Ainsi, un premier test a été fait avec la 'lutte étagée ciblée sur le cotonnier' (LEC) dans un de nos villages sites. Dans ce village, 11 participants ont été formés à cette nouvelle technique de traitement du cotonnier au cours de la campagne 1993/1994 et, la campagne suivante (1994/1995), le village avait décidé de passer entièrement en lutte étagée en s'appuyant sur les participants CdG pour former et suivre leurs paires dans la mise en pratique. Cette expérience nous a permis d'établir des critères auxquels doivent répondre les participants CdG pour devenir 'paysan-animateur'. Ces critères sont : la qualité et la compétence techniques, le bon niveau d'alphabétisation, la volonté de jouer le rôle d'animateur et l'acceptation de l'animateur par le groupe cible.

Par ce jeu, on pense que l'adoption en masse de certaines pratiques améliorantes au niveau des exploitations (aménagement des champs cultivés par exemple), permettra d'aboutir à la gestion des ressources naturelles au niveau du terroir villageois. C'est alors l'autre sens du raisonnement qui va d'une approche 'exploitation' vers une approche 'globale' au niveau sous-terroir ou terroir.
Telle que conçue, la logique d'extension de l'effort de réflexion et de certains résultats du CdG aux non alphabétisés part de l'hypothèse que:

- la gestion technique et économique des exploitations agricoles est un facteur clé pour le développement des exploitations au stade actuel en zone cotonnière.
- le noyau d'alphabétisés et/ou scolarisés en CdG s'approprie la démarche entièrement, lui permettant de mener des animations au niveau des différents groupes sociaux respectifs (quartiers, lignages, etc...) sur des notions de gestion économique

et technique simples en relation avec les solutions ou proposées pour améliorer le pouvoir et la qualité de la prise de décision.

A priori si cela est effectif, les agents de vulgarisation deviennent des conseillers et formateurs (dans un processus de formation participatif) des producteurs. Ainsi, ils formeront au fil de plusieurs années, davantage de producteurs alphabétisés et/ou scolarisés dont la maîtrise du CdG permettra d'atteindre un niveau de productivité meilleur avec une application des techniques visant la durabilité des systèmes de production.

Le CdG est un outil de formation intensive des producteurs sur la gestion technique et économique de l'exploitation agricole. Pour ce faire, un ensemble de supports ont été conçus pour faciliter sa mise en œuvre.

E) Les supports du CdG

Ces supports sont conçus pour:
- permettre de collecter des données techniques quantitatives ou qualitatives au niveau exploitation; ce sont les carnets individuels de conseil de gestion;
- contenir un minimum d'informations techniques sur certains thèmes d'actualité: ce sont les fiches techniques et modules de formation.

Ces supports ainsi que les données et informations qu'ils contiennent, permettent d'alimenter la réflexion et nourrir les discussions au cours des séances conseil de gestion et les différentes visites sur le terrain.

E1) Le carnet CdG

Il est constitué d'un ensemble de fiches traitant différents aspects de la production et de la gestion. Ces fiches sont structurées en tableaux (pour les informations qualitatives et les prises de décision). Elles permettent d'une part la collecte de l´information et l´analyse technico-économique des résultats et d´autre part, la formulation de propositions d'amélioration. Les différents tableaux peuvent être regroupés sous les rubriques suivantes :

- la structure de l'exploitation faisant ressortir le nombre de bouches à nourrir mais surtout le potentiel de travail sous les aspects humains et matériels (actifs champs, actifs bergers).
- la production végétale faisant ressortir le plan de rotation, la situation des techniques culturales sur les différentes cultures et les résultats de la campagne (estimations de rendement et production).
- l'analyse technico-économique des résultats par culture permettant une comparaison de différentes spécialisations à partir de prix réels des marchés (officiels ou courants) et d'hypothèses de prix.
- la situation de la production animale touchant des domaines de la conduite de l'élevage, de la valorisation des entrées et sorties, d'un compte de trésorerie.
- l'analyse des résultats globaux de l'exploitation traitant de l'autosufisance alimentaire, de la situation foncière, de la trésorerie.
- le plan de campagne prévisionnel avec des objectifs de production et de rendement prenant en compte les innovations à développer.

E2) Les fiches techniques et modules de formation

Ils traitent des différentes actions techniques qui, en fonction des contraintes identifiées, permettent d'améliorer la production ou le système de production en général. Les fiches techniques se rapportent plus précisément sur des innovations introduites ou proposées. Elles contiennent les informations techniques dans un langage assez accessible pour les conseillers. Par ailleurs, des traductions en langue nationale dioula sont faites dans un langage plus simple à l'usage des producteurs formés, pour leur permettre de garder l'information sous une forme écrite. Elles touchent des thèmes comme l'aménagement des parcelles cultivées pour lutter contre l'érosion, l'installation de soles fourragères, les étables et fosses fumières, la pratique de la culture du riz pluvial, la conduite des pépinières, etc.

On s'aperçoit que le conseil de gestion demande un intense travail. Aussi, il est important de programmer dans le temps, l'ensemble des thèmes à traiter (aussi bien du carnet CdG que des actions concrètes s'y rapportant), de façon à aborder chacun d'eux au moment opportun.
Un planning prévisionnel des séances CdG est présenté à titre d'exemple en annexe. Il est facile à concevoir par les agents de terrain en s'inspirant de leur connaissance du milieu. Selon Mercoiret et Mercoiret (1994), les producteurs ont besoin d'informations articulées sur leurs préoccupations, diversifiées et présentées de façon accessible et attrayante.

La méthode du conseil de gestion telle qu'elle a été présentée ci-dessus, met plus l'accent sur l'exploitation agricole et les problèmes de gestion qui se posent à ce niveau. Il existe d'autres domaines de production pour lesquels une approche du type conseil de gestion pourrait en améliorer le fonctionnement du processus. C'est le cas des éleveurs pour qui, le schéma global d'approche ci-dessus présenté nécessite d'être adapté à la spécificité du groupe. Il est donc développé un conseil de gestion aux éleveurs.

F) Le conseil de gestion aux éleveurs

Tel que conduit avec les agriculteurs, il est possible d'animer un conseil de gestion avec des éleveurs. La difficulté à ce niveau est le faible taux de scolarisation et/ou alphabétisation dans la zone cotonnière dans leur milieu. Il s'agit donc d'un conseil de gestion basé sur des discussions orales avec quelques prises de notes entre les techniciens et le groupe de pasteurs. Ces discussions portent sur le diagnostic des contraintes et les stratégies de gestion des troupeaux en conséquence. La démarche consiste à s'appuyer sur la structure du troupeau et son suivi, pour bâtir un plan de gestion de l'alimentation et de la santé prenant en compte les stratégies de production des éleveurs pris individuellement. Il doit aboutir à une prise de conscience pour une meilleure gestion de la production animale afin de l'orienter vers un type d'élevage plus économique.

F1) Gestion de l'alimentation

Les déplacements des troupeaux à différentes échelles spatiales constituent une stratégie des pasteurs face aux contraintes d'alimentation et d'abreuvage des animaux. Pour améliorer cette pratique; il convient d'envisager une gestion de l'alimentation prenant en compte:

- la sensibilité des animaux au manque de pâturages occasionnant de grands déplacements en saison sèche (sauvetage de veaux, entretien de femelles gestantes ou de certaines vieilles vaches);
- les objectifs de production de l'éleveur (production laitière, embouche, etc...);
- la disponibilité en ressources alimentaires et d'eau pour l'abreuvage, et...

F2) Gestion de la santé

Par une analyse de la structure du troupeau, on cherche à définir avec les éleveurs, les différentes classes d'animaux les plus sensibles aux principales maladies de la zone.

Pourtant, on définit des stratégies de protection sanitaire ciblée (celle complète n'étant pas envisageable en milieu peulh) des différents élevages. Le raisonnement aboutit à une évaluation quantitative des traitements courants sur les animaux (vaccins divers, déparasitants, etc...) et d'en évaluer les coûts. Ceci constitue le plan prévisionnel des traitements courants, les interventions circonstancielles n'étant pas incluses.

Le plan prévisionnel de gestion sanitaire ainsi établi, doit spécifier les différentes périodes optimales d'exécution en relation avec la programmation des services vétérinaires et les mouvements des pasteurs. L'objectif est d'arriver à des stratégies de complémentation à partir des ressources mobilisables sur place (paille de brousse, résidus de récolte, sous-produits agro-industriels = SPAI) et d'introduire des innovations comme la culture fourragère ou le traitement de la paille à l'urée. Ces différentes actions nécessitent un important travail si bien que pour être efficaces, il faut une programmation en vraie grandeur. Les critères de choix des animaux devant faire l'objet d'un traitement particulier étant relatives, on peut arriver à cibler le travail selon les moyens mobilisables par le producteur. On doit arriver à quantifier les besoins de façon compréhensible (superficie de la sole fourragère nécessaire, le nombre de sacs de SPAI, de pierre à lécher, etc.).

Ainsi, un conseil de gestion aux éleveurs répond à plusieurs objectifs :
- formation des éleveurs sur les techniques d'alimentation du bétail mises au point par la recherche;
- information sur les produits alimentaires disponibles sur le marché et leur utilisation;
- gestion des animaux avec un esprit d'agir en fonction d'objectifs de production, de ce qui est mobilisable sur place, et des moyens d'acquérir ce qui manque.
- sensibilisation sur la nécessité d'introduire un certain nombre d'innovations pour améliorer la productivité de l'élevage dans un environnement de plus en plus fini.

Discussions/Perspectives/Conclusion

A) Discussions.

La méthode du CdG a l'avantage d'associer les producteurs dans un processus d'analyse et de diagnostic des systèmes de production en général avec une prise en compte de l'environnement économique pour la prise de décision.

La contrainte majeure est la présence de paysans alphabétisés et/ou scolarisés qui ont souvent un niveau d'instruction assez faible. Elle a l'inconvénient de demander un travail plus intense de la part des agents de vulgarisation, un travail de formation et d'action obligeant à lire pour se former et s'informer.

Le processus permet une prise de conscience dans sa situation, à partir de laquelle on cherche un cheminement d'amélioration. Mais, on est vite confronté au problème de manque d'équipement alors qu'au même moment, on assiste à un désintéressement du crédit à l'équipement par les organismes de crédit. Ce désintéressement est le fait d'importants crédits contractés par le passé et qui sont restés impayés. Une autre raison plus directe est son coût élevé pour la plupart des exploitations agricoles (INERA/RSP-RD, 1994). La situation n'est pas bloquée pour de bon, mais le processus d'évolution est très lent.

Par ailleurs, il existe des contraintes se situant en amont et en aval du niveau exploitation, dont il faut tenir compte forcément. C'est l'exemple des prix des intrants et de l'équipement, mais surtout l'insécurité du prix d'achat minimum aux producteurs.

L'extension de la méthode du conseil de gestion de manière à toucher les exploitations ne comportant pas d'alphabétisés et/ou de scolarisés demeure une question importante pour son adoption à grande échelle géographique. Aussi, l'ensemble des méthodes d'approches utilisées jusqu'ici, font l'objet d'un suivi en vue de juger de leur pertinence. Cependant, on pense que vu l'intérêt manifesté par les producteurs pour la méthode, des formes plus appropriées de mécanismes d'extension pourront être trouvées du moins localement. Il est vrai que l'approche 'paysan animateurs', sans comporter une contre-partie de compensation peut paraître faite par les producteurs non alphabétisés au niveau du village et du quartier.

Cette approche concernant la gestion des exploitations peut trouver d'autres domaines d'application comme la gestion des groupements villageois, des groupes de commercialisation, des ressources naturelles... Ce qui permettra au système de mieux fonctionner dans son ensemble.

B) Perspectives

La démarche 'conseil de gestion' telle que décrite est restée jusqu'ici expérimentale dans le cadre du programme R-D avec le PDRI/HKM malgré une volonté d'extension manifestée par le CRPA. Dans cette perspective, il convient de se poser la question à savoir, comment insérer cette approche dans le système national de vulgarisation; somme toute, elle n'est pas une remise en cause de ce système, mais peut enrichir le contenu des programmes à réaliser à condition que l'outil soit intégré au système comme programme principal. Il est certain qu'une quelconque application en parallèle du CdG au'training & visit' obligera les vulgarisateurs de base à travailler à la fois sur deux systèmes, donc à être moins efficaces.

Ainsi, chaque conseiller agricole de base peut animer plusieurs groupes d'alphabétisés à l'intérieur de sa zone d'encadrement et réaliser le suivi des autres groupes animés par les paysans animateurs. En suivant le rythme des quinzaines, ils mèneront des activités de formation et de tests de démonstration en appliquant la méthode CdG. Cependant, il faut comme mesure d'accompagnement, trouver un moyen pour un minimum d'approvisionnement de la part des services publiques.

C) Conclusion

Après deux années de mise au point, la méthode du conseil de gestion en zone cotonnière du Burkina Faso semble avoir tous ces contours dessinés. Des séances théoriques en salle à la mise en place des innovations, à leur extension aux non-alphabétisés ainsi qu'à son application à des groupes spécifiques comme les éleveurs, il reste certainement encore des points à éclaircir.

A partir de ces séances conseil de gestion, il est certain que les producteurs s'approprient beaucoup de connaissances sur les notions et innovations introduites. Leur mise en application doit se traduire par une amélioration des pratiques, stratégies et niveau de production, phénomènes toute fois pas appréciables à leur juste valeur dans le court terme. Cependant, on peut déjà apercevoir une nouvelle approche plus intégrée de la vulgarisation agricole associant plus fortement les spécialistes des productions animale et végétale.

Malgré ses principes participatifs, le transfert de technologies à l'intérieur du système dépend toujours sinon du dynamisme des agents de vulgarisation (à toutes les échelles) chargés de sa mise en oeuvre. L'utilisation des acquis et principes de la démarche pour aborder les autres problèmes en amont et en aval de la production agricole, notamment l'appui des organisations paysannes rendra l'outil plus opérationnel au niveau exploitation.

Aussi, la méthode du conseil de gestion n'est pas contradictoire au système 'Training and Visit' mais intègre bien d'améliorations; de ce fait, son intégration en double comme alternative dans le système de vulgarisation en zone cotonnière semble possible.

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Devaluation and New Technology Introduction in the Sudanian and-Sudano-Guinean Zones of Mali

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Abstract

In the semi-arid zones, the principal emphasis of technology introduction has been on new cultivars and animal traction. Technology development has been very successful in the Sudano-Guinean zones, where new cotton and maize technologies have included the combination of new cultivars, improved agronomic practices, and rapidly increasing levels of chemical inputs especially inorganic fertilizers. With declining levels of organic matter in the soils here, the devaluation of the FCFA in January 1994, and the elimination of the input subsidies, there has been concern with the direction of the new technologies for this region, especially the soil fertility problem and how it will be affected by the higher prices of imported chemicals. With programming, we look at the potential effects of the new technologies and especially how they will be affected by the recent devaluation and other accompanying policies such are the changes in input supply and credit to farmers.

In the Sudanian region, there is less and more irregular rainfall than in the Sudano-Guinean region and generally the soils are more fragile and less fertile. There has been rapid introduction of animal traction, ridging, and new cereal and cowpea cultivars. However, the soil-fertility problem is now the principal constraint. Before the devaluation, the anti-agricultural economic regional and generally the soils are more fragile and less fertile. There has been rapid introduction of animal traction, ridging, and new cereal and cowpea cultivars. However, the soil-fertility problem is now the principal constraint. Before the devaluation, the anti-agricultural economic policies of an overvalued exchange rate and other policies subsidizing imported cereals pressured Sudanian region farmers to retreat to subsistence-oriented strategies in which they minimized their marketed output shares and their use of purchased inputs. The conventional wisdom has been that there was something different about Sahelian or African farmers with regard to marketing and input use rather than a result of poor agricultural and economic policy choices by governments. These policies are being corrected, so it is appropriate to evaluate the potential technological changes now made possible by the availability of new cultivars responsive to inputs and the more profitable economic environment and, in the Sudanian region, the increased water retention made possible by the widespread diffusion of the ridging through animal traction.

Résumé

Dans les zones semi-arides, l'accent a été principalement mis sur de nouveaux cultivars et la traction animale en ce qui concerne l'introduction de technologies. La mise au point de technologies a connu un grand succès dans les zones Soudano-guinéennes où les nouvelles technologies de production de coton et de maïs ont comporté la combinaison de nouveaux cultivars, de pratiques agronomiques améliorées et l'application progressive d'intrants chimiques, particulièrement les engrais minéraux. Avec la baisse des niveaux de matière organique dans le sol ici, la dévaluation du FCFA en Janvier 1994 et la suppression des subventions aux intrants, des préoccupations ont été exprimées quant à l'orientation des nouvelles technologies pour cette région, surtout en ce qui concerne le problème de fertilité des sols et l'impact de l'augmentation des prix des produits chimiques importés sur ce volet. En élaborant notre programme, nous cherchons à connaître les effets potentiels des nouvelles technologies et surtout à savoir comment ces technologies seront affectées par la récente dévaluation et autres politiques d'accompagnement comme les modifications du système de fourniture d'intrants et de crédit aux paysans.

Dans la région Soudanienne, la pluviométrie est moindre et plus irrégulière que dans la région Soudano-guinéenne. En outre, les sols sont généralement plus fragiles et moins fertiles. Si l'introduction de la traction animale, du billonnage et de nouveaux cultivars de céréales et de niébé a été rapide, le problème de fertilité du sol demeure cependant la contrainte majeure à l'heure actuelle. Avant la dévaluation, les politiques anti-agroéconomiques d'un taux de change surévalué ainsi que d'autres politiques de subvention de céréales importées exerçaient une telle pression sur les paysans de la région Soudanienne que ceux-ci se contentaient d'adopter des stratégies de subsistance qui leur faisaient minimiser leurs parts de production commercialisée et leur utilisation d'intrants achetés. La croyance traditionnelle a été qu'il existait une différence au niveau des paysans Sahéliens ou Africains en ce qui concerne la commercialisation et l'utilisation d'intrants, plutôt que de penser qu'il s'agissait du résultat de mauvais choix de politiques agricoles et économiques adoptés par les gouvernements. Ces politiques font actuellement l'objet de correction et de ce fait il convient d'évaluer les changements technologiques potentiels que permettent maintenant la disponibilité de nouveaux cultivars sensibles aux intrants, l'environnement économique plus rentable et, dans la région Soudanienne, l'augmentation de la capacité de rétention d'eau grâce à une large diffusion du système de billonnage par la culture attelée.

Introduction

In the semi-arid zones the principal emphasis of technology introduction has been on new cultivars and animal traction. Technology development has been very successful in the Sudano-Guinean zones, where new cotton and maize technologies have included the combination of new cultivars, improved agronomic practices, and rapidly increasing levels of inorganic fertilizers. Local cereals, sorghum, and millet technologies have not been as successful as cotton and maize. Farmers still use local cultivars of sorghum and millet with low levels of inorganic fertilizers.

With declining levels of organic matter in soils here, the devaluation of the FCFA in January 1994 and the elimination of input subsidies, there has been concern with the direction of the new technologies for this region, especially concerning soil fertility problems and how they will be affected by the higher prices of imported inorganic fertilizers. With programming, we look at the reasons for lower rates of introduction of sorghum and millet technologies versus cotton and maize and assess the potential effects of the new technologies of millet and sorghum, especially how they will be affected by the recent devaluation and other accompanying policies, such as the changes in input supply and credit to farmers.

In the Sudanian region, there is more irregular and less volume of rainfall than in the Sudano-Guinean region. Generally, the soils are more fragile and less fertile. There has been rapid introduction of animal traction, ridging, and some new cereal and cowpea cultivars. Still, cereal technologies for millet and sorghum combined with moderate levels of inorganic fertilizers have not been adopted as expected. The soil fertility problem is now the principal constraint in the Sudanian zone because ridging (a soil preparation/water retention technique) and animal traction are pervasive. The devaluation and the removal of input subsidies may further hinder the adoption of improved cereal technologies in the Sudanian zone.

The paper attempts to explain the reasons for the lesser success achieved in sorghum and millet technologies in the Sudano-Guinean and the Sudanian zones and to assess the impacts of the devaluation on the adoption of improved crop technologies in the Sudano-Guinean and Sudanian agroecological zones. It makes policy recommendations to encourage adoption of cereal technologies critical for sustaining crop production and increasing farm incomes in the two regions.

Regions and New Technologies Developed

The study focused on two agroecological regions of Mali: The Sudano-Guinean and the Sudanian regions that have differences in soil fertility, rainfall quantities and distribution, input and product markets. Therefore, the two regions have different potentials for new crop technologies to be adopted. The new technologies considered are mainly the new cultivars of cereals, groundnuts, and cowpea combined with inorganic and organic fertilizers and water retention techniques. Improvements of cotton and maize activities are also considered for the Sudano-Guinean zone.

The Sudano-Guinean Zone

The Sudano-Guinean agroecological region is characterized by higher rainfalls, ranging from 800 to 1200 mm per year nine years out of 10. It is endowed with better soils compared to the Sudanian region. Technological change has affected this region more than anywhere else in the country due to its greater resource endowments and the concentration of research and policy efforts here. Higher rainfall, better soils and institutional support have facilitated the adoption of new cultivars of cotton and maize and associated technologies, including inorganic fertilizers, pesticides and improved cropping practices such as the use of animal traction. The use of animal traction is widespread and almost all the farm households own at least a set of animal traction equipment, including a plow and a pair of oxen (ESPGRN, 1994). Inorganic fertilizers are mainly used on cotton and maize but this technological change did not spread to sorghum and millet, a challenge yet to be addressed by researchers, extensionists, and policy makers. Farmers use an average of 130 kg of compound fertilizers and 45 kg of urea per hectare on cotton.

There has also been a rapid introduction of new maize technologies during the early 1980s. New cultivars of maize were used on over one-third on the maize area in Mali in 1986 (Sanders, *et al.*, 1995, p. 90). The rapid diffusion of new maize cultivars combined with inorganic fertilizers is linked to the sufficient rainfall in the Sudano-Guinean region, the supply of a subsidized credit for inorganic fertilizers, and guaranteed higher prices for maize. The use of inorganic fertilizers has increased rapidly in the last two decades in this region but has been concentrated on high-yielding cultivars of cotton and maize. Local cultivars of sorghum and millet are used and little inorganic fertilizers is used on these crops which share more than half the total area cropped. Local cultivars of sorghum and millet do benefit from the residual fertilizers used on cotton and maize as they are rotated on this fertilized land. However, there was a decline in fertilizer consumption in the second half of the 1980s as input subsidies were eliminated. The central question of this paper is : Why have high-yielding cultivars of cotton and maize been rapidly adopted and farmers are still using local cultivars of sorghum and millet with low levels of inorganic fertilizers ?

Table 1. Technologies Successfully Introduced in the Two Principal Agroecological Regions for Crop Production in Mali.

Zones	**Present technologies**	**Potential technologies**	
		Water availability	Soil fertility
Sudano-guinean	New cotton and corn cultivars with inorganic fertilizer and improved agronomic practices. Improved agronomy and inorganic fertilization on maize and sorghum. Rapid increase in use of organic fertilizers.	Sufficient rainfall in most years in this zone	Fertilizer. Selected for low soil-fertility conditions.
Sudanian	Contour dikes and organic fertilizer. Early cereal and cowpea cultivars. In Mali, ridging and increases in organic fertilizers	Holds the runoff water. Earliness gives drought escape.	Increase in use of inorganic fertilizers.

Source : Adapted from Sanders, Shapiro and Ramaswamy, 1995.

1) The Constraints in the Sudano-Guinean region

The main constraints in the Sudano-Guinean region are two-fold:

a) Soil Fertility

A critical issue in the Sudano-Guinean cropping system is the pressure on land due to increasing human and animal populations. Farmers have been increasing their investments in livestock since the 1970s and 1980s. The breakdown of the traditional transhumance systems in drier areas following the drought has led to migration of herders to the Sudano-Guinean region for permanent settlement. Moreover, the drier Sudanian and Sahelo-Sudanian farmers have been migrating into this higher rainfall zone, hence the pressure on land has been increasing rapidly during the last decade. Even though inorganic fertilizers are used at moderate rates on cotton and maize, the rates on sorghum and millet are so low that soil mining is an increasing problem. Moreover, the use of inorganic fertilizers on sorghum and millet has been reduced with the removal of inorganic fertilizer subsidies in the 1980s.

With the pressure from foreign exchange constraints and the increasing cost of fertilization with the devaluation, the government encourages the development of alternatives to inorganic fertilizers that use local inputs. Among these alternatives are cereal/legume rotations, local rock phosphate and better use of manure. However, since the primary nutrient deficiencies are nitrogen and phosphorus, inorganic fertilizers are presently the most concentrated and lowest cost sources of these principal nutrients (N and P) in the Sudanian-Guinean zone. These other alternatives tend to be poor substitutes for inorganic fertilizers. The critical problem is how to increase crop yields when the principal constraints are the low levels of the basic nutrients, N and P.

b) Cultivars responsive to soil fertility improvements

To maximize the response to an improved agronomic environment (soil amendments), new cultivars become necessary. High-yielding cultivars are presently used only for cotton and maize in this region. Farmers use local cultivars of millet and sorghum, the staple food crops, which share more than half of the total area cultivated. Local cultivars in low-input environments can tolerate stress conditions, but do not respond well to moderate to high inputs. Stress tolerance and high yields are often competing characteristics. One hypothesis of our research is that there are prospects for substantial gains in sorghum and millet yields in the Sudano-Guinean region by employing new cultivars of millet and sorghum conbined with inorganic and organic fertilizers. Breeding and improved agronomy are both important in technology development of the Sudano-Guinean region.

2) Potential Technologies for the Sudano-Guinean Zone

The potential new technologies for the region considered here are improved cultivars of sorghum, millet, and groundnut combined with inorganic and organic fertilizers. Among potential cereal technologies are medium-cycle improved local cultivars of sorghum, CSM 388 and Malisor 84-7, and an introduced new cultivar of millet, IBV 8001. All of the above new cultivars have shown substantial yield potential when combined with moderate levels of inorganic fertilizers on experiment stations and on-farm trials. Another improvement in the technologies actually used is to apply higher levels of inorganic fertilizers on cotton and maize following agronomists' argument that to maintain soil fertility and avoid soil mining, higher levels of inorganic and organic fertilizers should be applied to these crops (van der Pool, 1992; Dureau, *et al.*, 1994;

ESPGRN, 1994). After the elimination of inorganic fertilizer subsidies following the structural adjustment programs of the 1980s, the demand for increased organic manure increased a response to the relative price signals (Sanders, Shapiro, and Ramaswamy, 1995). The production of 'higher quality' manure with mixture of straw with animal wastes (called "litiere"), and the compost from the watered and covered compost pits are increasing. These qualitative improvements have extended the quantity and quality of manure available from a given animal stocks. However, there are still effective constraints on the supply of manure available depending upon animal stocks and the manure processing technology. There is no market for manure. We consider in more detail the farm-level options for organic and inorganic fertilizers with our programming models, but due to the limited potential for output increase of manure, the focus is the introduction of improved cultivars of sorghum and millet combined with inorganic fertilizers.

The Sudanian Region

The Sudanian agroecological zone has annual rainfall ranging between 600 and 800 mm. The production environment is harsh with intra-annual and inter-annual rainfall variability, low fertility and fragile soils. The main constraints are soil fertility and water availability.

1) The Constraints in the Sudanian Region

a) Water Availability

Adequate water availability to the plants is a constraint when rainfall is low and irregular. Applying inorganic and organic fertilizers without an adequate level of water is risky because the response to the fertilizer depends on the availability of moisture at the critical stages of plant development (Sanders, Shapiro and Ramaswamy, 1995, p. 66). The effects of low and erratic rainfalls are aggravated by soil crusting that leads to reduced water infiltration. The water retention techniques will help decrease production risk. Implementation of various water-retention techniques is made economically feasible by widespread animal traction use in the Sudanian zone. Farmers in this region are already utilizing ridging for millet and sorghum and deep plowing for groundnut in most of the zone. These techniques provide some water retention thereby raising the potential returns to improving soil fertility. Other water retention techniques to be considered in the modeling are discussed in the section on potential technologies.

b) Soil Fertility

The main constraint in the Sudanian region is land quality. Low and declining soil fertility combined with seasonal plant water stress have been serious constraints to crop yields. As land quality deteriorates, cereal yields as well as other crop yields have been falling. To compensate for low yields, farmers have been pushing cultivation onto more marginal crop areas to reach their production/consumption goals, further depleting and degrading the soil.

The cropping systems are not sustainable without combined soil fertility improvements and water retention techniques. Researchers have been evaluating substitutes for inorganic fertilizers in the Sudanian region as well. Manure production and improvement through compost pits have been spreading during the last five years. The limited quality of manure produced is spread on the less fertile parts of the fields. Further research to find low-cost complementary activities to inorganic fertilizers that would thereby reduce the costs to farmers should be carried out, but our hypothesis is that increasing farm-level yields and incomes without moderate levels of inorganic fertilizer use will not be economically feasible.

c) Cultivars Responsive to Soil Improvement and Water Availability

When the crop environment is improved through the simultaneous introduction of more water retention and inorganic and organic fertilizers, local cultivars will not be sufficient to substantially increase the yields. New cultivars which are more responsive to improved soil and water environments are needed and there will be a payoff with them. Our hypothesis it that new cultivars of millet and sorghum principally, and then cowpea and groundnut with moderate levels of inorganic and organic fertilizers would be adopted by farmers. Some early maturing improved cultivars of millet and sorghum, groundnut, and cowpea are used, but with low levels of inorganic fertilizer. Increasing the levels of inorganic fertilizers on existing improved cultivars and adopting others combined with moderate levels of inorganic fertilizers with the existing water retention technique (ridging for cereals and deep plowing for groundnut and cowpea) will substantially increase farm incomes.

In summary, the central problem in the Sudanian region is its harsh environment with low and irregular rainfall, multiple soil fertility problems, including very low levels of the two basic nutrients (nitrogen and phosphorus), and minimal use of purchased inputs. Introducing new cultivars of sorghum and millet to be combined with moderate levels of inorganic fertilizers, and increasing the levels of inorganic fertilizers on existing improved cultivars to increase farm incomes are the challenges in the Sudanian zone.

2) Potential Technologies for the Sudanian Region

Compared to the Sudano-Guinean zone, the Sudanian region presents more technological challenges. The potential technologies introduced in the models as potential activities to be adopted by farmers are : inorganic and organic fertilizers, water retention techniques such as tied ridging, deep plowing followed by tied ridging, inorganic and organic fertilizers, water retention techniques, and improved cultivars are yield increasing and aimed to address the constraints in the Sudanian region.

An important innovation in the Sudanian region has been the development of shorter-season cultivars of millet, sorghum, groundnut and cowpea (Sanders, 1994, p. 4). There has been a diffusion of improved cultivars both between farmers and from the experiment stations since the drought of 1968-73. The improved millet and sorghum cultivars being slowly adopted have an ability to escape drought due to their short to medium cycles. Most of the crop cultivars being tested or proposed to farmers are early maturing, improved local cultivars : Tiemarifing, Malisor 84-4, Malisor 84-5 for sorghum and M2D2, Toroniou de Ningari, and NKK for millet. They have good yield potential when combined with soil fertility and water retention techniques. Besides cereals, improved leguminous crops are being adopted by farmers. The improved cultivars of groundnut, 28-206 and 47-10, and the improved cowpea cultivars, KN1, TN8863, TVX3236 and SUVITA2, are early maturing and high yielding. The 47-10 groundnut is an early maturing variety which was used by farmers in the area previous to the collapse in 1982 of the O.A.C.V., an integrated rural development parastatal which used to provide the cultivars and accompanying input to farmers.

A potentially important crop in the area can be cowpea if the necessary crop management and improved input and output markets are provided. The models assess the profitability of improved cultivars when combined with different levels of inorganic and organic fertilizers, and different water retention soil preparation techniques-ridging, tied ridging, deep plowing, deep plowing followed by ridging, and by tied ridging. Our hypothesis is that improved cultivars combined with fertilizers and water retention techniques will have a high payoff.

Input Supply, Policy Changes and New Technologies

a) Input Supply and Credit System

A major change occurred in the supply of input following the structural adjustment policies in the early 1980s, shifting the supply of input through credit to farmers from a centralized parastatal, SCAER, to a rural development bank and to private sectors operating through integrated rural development projects and organizations. In the Sudano-Guinean zone, input is provided to farmers through credit for cotton only, which also benefits from guaranteed output prices. But the cotton input credit is rationed to control the area cropped in cotton following the cotton price crash in the international markets in 1985. There is no credit for input (inorganic fertilizer) for the other crops. In the Sudanian zone, no input-tied credit is available for millet, sorghum, groundnut and cowpea and the input (insecticides, inorganic fertilizer) are available on cash payment basis.

b) Devaluation

In January 1994, F CFA zone countries went through a 50% devaluation of the CFA currency against the French franc, the first parity change between the two currencies since 1948. This policy reform affects input and output prices, supply and demand of inorganic fertilizers by farmers, new technologies adopted by farmers, farm incomes and cropping strategies, especially in the Sudano-Guinean zone where cotton (the major export crop of the country) is produced. The short-run effects of the devaluation are the increase in inorganic fertilizer prices, the increase in cotton price, and a moderate increase in cereal prices. In Mali, the government decided to increase the inorganic fertilizer and cotton insecticide prices by 60% for the next cropping season. The cotton price has been raised for the next cropping season (1995-96) by the government to 120 F CFA from 85 F CFA, an increase of 35 % and the control of cotton area will be removed starting with the next cropping season. The cereals and groundnut prices have only slightly increased (10%) due to the good rainy season which kept cereal prices low. In the long run, we assume that the demand for millet, sorghum, groundnut and cowpea will increase due to some substitution for imported wheat and rice by processed local cereals. Also, the increase in livestock exports with devaluation will increase the demand for processed cereal by-products as feed.

Devaluation will be analyzed for the short-run and the long-run with changes in prices and credit policies. We consider two scenarios for the long-run impacts of devaluation: a scenario in which these crop prices increase by 25 % and another in which prices increase by 40%. A critical question asked by policy makers, researchers and private fertilizer supplies is how all these price changes resulting from the direct and indirect effects of devaluation will affect crop profitability, farmers' cropping strategies, and consumption of inorganic fertilizer. Some analysts within CMDT (Giraudy and Niang, 1994) have used partial budgeting to show that cotton returns will increase with devaluation, but the analysis should also be done at the whole farm level to analyze the whole farm choices that include new cereal technology options and how these product and input choices are affected by devaluation.

Methodology

To evaluate the farm level potential of the new technologies, farm budgeting is used first to evaluate the profitability of each crop activity, and then mathematical programming is undertaken that constructs representative farm models. Mathematical programming is used to address several research questions such as : With several technologies being profitable and many combinations available, what are the technologies chosen and at what levels of input use and area cultivated ? Are there on-farm constraints impeding adoption of the new technologies? How sensitive is technology adoption to economic policies ?

Models for these regions with their substantial rainfall and price variability need to include risk. The main outputs from the mathematical analysis are the potential impacts on farm incomes of the technologies and associated policies affecting the introduction of the new technologies. A key policy to be assessed in this paper is why there has been continuing and often rapid introduction of cotton and maize technologies and a lagging adoption of sorghum and millet technologies. Central to recent policy concerns, how will cereal technology adoption be affected by the recent devaluation of the CFA ? Devaluation impacts are assessed through input and output price changes in the models.

Results

The results are organized into three scenarios : potential impacts of new technologies before devaluation, short and long run impacts of devaluation on the introduction of new technologies on farm incomes, and on the demand for inorganic fertilizers. These impacts are evaluated for both agroecological regions.

1) The Sudano-Guinean Region

a) Impact of New Technologies on Farm Incomes before Devaluation

The current technologies consist of high-yielding cultivars of cotton with high levels of inorganic fertilizers close to the recommended doses, and high-yielding cultivars of maize with a moderate level of inorganic fertilizers plus local cultivars of sorghum and millet combined with low levels of inorganic and organic fertilizers. The moderately risk averse farmer (average farmer) allocates a total of 13 ha to crops with 8 ha to local cultivars of sorghum and millet, 3 ha to cotton 1 ha to maize, and 2 ha to groundnut and other crops. The area cropped in cotton is bound to 3 ha for an average farm due to the input rationing aimed to control the area cropped in cotton following the cotton price crash in the international market in 1985. Sorghum and millet are important in terms of area but yet use local cultivars with small quantities of inorganic fertilizers. The local cultivars of sorghum and millet combined with high levels of inorganic fertilizers increase farm returns by only 36% and 13%, respectively. Local cultivars are responsive to inorganic cultivars of sorghum combined with higher levels of inorganic fertilizers have higher yield response and returns. The increases in yields and returns are, respectively, 92% and 58%, compared to actual practices when the same levels of inorganic fertilizers are applied. The improved cultivars of millet so far have much lower yield increases and returns and millet is more adapted to the Sudanian zone than the Sudano-Guinean, which has higher rainfall. In the choice between alternative activities, the returns per hectare of cotton and maize are higher and are, respectively, 70,000 and 55,000 CFA compared to 45,000 and 30,000 CFA for improved cultivars of sorghum and millet combined with higher doses of inorganic fertilizers, respectively. Farmers tend to invest the cash available in cotton and maize.

Table 2. Profitability of Current and Potential Millet and Sorghum Technologies in the Sudano-Guinean Zone (Results from Farm Budgeting before Devaluation).

Cultivars and fertilizers	Expected yields Kg/ha (9 years)	Percentage increase in yields	Expected returns CFA/ha (9 years)	Expected returns CFA/ha
A. Local cultivars				
1. Sorghum + e Fert.	696	(1) 75	28350	(1) 36
2. Sorghum + Fert.	1222		38585	
3. Millet + e Fert.	660	(3) 68	27310	
4. Millet + Fert.	1114		30985	(3) 13
B. Improved cultivars				
	1340	(1) 92	44775	(1) 58
5. Sorghum + Fert.	2137	(1) 207	64700	(1) 128
6. Sorghum +Fert. + Manure	1578	(3) 139	30210	(3) 6
7. Millet + Fert. + Manure				

NB : The soil preparation technique used for all the trials is ridging which is water-conserving. Fert. refers to 100 kg of complex cereal and 50 kg of urea. e fert. refers to a small amount of fertilizers used per hectare (10 kg of complex cotton and 10 kg of urea). Manure refers to 5 t/ha. (1) compared to treatment 1, (3) compared to treatment 3. The exchange rate before devaluation was $1 = CFA 250, after devaluation it is $1 = CFA 500.

When improved cultivars of sorghum and millet are combined with inorganic fertilizers levels and manure, expected yields increase by 200% and the expected returns by 125%. The main constraint for this technology is the finite supply of manure as shown in the whole farm programming models. Higher levels of inorganic fertilizers on cotton, have been recommended by agronomists in the main cotton research station in Mali following their research results. They conclude that cotton yields have been stagnant for the last half a decade due to declining soil fertility and that the crop environment should be improved instead of only concentrating on varietal improvement. Higher levels of inorganic fertilizers increase expected yields and returns of cotton by 60% and 70%, respectively, compared to the present practice.

In summary improved cultivars of sorghum and millet combined with higher levels of inorganic fertilizers are more profitable than local cultivars at the same levels of inorganic fertilizer levels. However, the returns to cotton and maize are still higher. Cotton benefits from credit, research, and a fixed price. Maize also received guaranteed prices and input-tied credit until 1986. Sorghum and millet do not benefit from credit, but increased credit for local cereals (with local cultivars) could lead to its use on cotton and maize. Inorganic fertilizers have been used for more than two decades on cotton and one decade on maize. Moreover, local cereals have been in the rotation, thus utilizing the residual fertilizer effects. Hence, it is probable that there has already been some selection of local cereals for responsiveness to inorganic fertilizers.

Impact of Devaluation on the Adoption of Improved Technologies

1) The Sudano-Guinean Region

a) *Short-Run Effects of Devaluation and New Technologies (No Change in Credit Policy, no Control of Cotton Area)*

With the above changes in prices, and if cotton area control were maintained, farmers would decrease the area cropped in improved maize combined with higher levels of inorganic fertilizers by 30% because of higher prices of input due to devaluation. According to the results of the model, farmers would still crop local cultivars of millet and sorghum and therefore would not adopt improved cultivars of millet and sorghum combined with moderate or higher levels of inorganic fertilizers. The increase in expected total farm income due to the short-term effects of the devaluation is 10%, and the total demand for inorganic fertilizers increases only by 5%.
When the cotton area control is lifted for the next cropping season, the net returns for cotton will double and total farm returns will increase by 40% with a corresponding increase in the demand for inorganic fertilizers of 25%. However, the short-term impact of devaluation does not encourage the adoption of improved cultivars of sorghum and millet with higher levels of inorganic fertilizers because of the increase in fertilizer prices (Table 3).

b) *Short-Run Effects of Devaluation with New Technologies (with Change in Credit Policy)*

When input-tied credit is made available for the cereals, improved sorghum cultivars with inorganic fertilizers are adopted in addition to cotton and maize according to the model. The credit will ease up the liquidity constraint which can be a major barrier at the beginning of the rainy season (Table 4). The total demand for inorganic fertilizers and the increase in farm income is 60% and 200%, respectively, due to the tied cereal credit, the increase in maize area, and elimination of the cotton area control.

Table 3. Short-Term Effects of Devaluation on the Profitability of Crop Technologies in the Sudano-Guinean Zone (No Change in the Credit Policy and no Control of Cotton Area).

Crop technologies	Risk neutral (r = 0)		Risk averse (moderate) r = 2		Risk averse (strong) r = 3	
	Area (ha)	Returns (cfa)	Area (ha)	Returns (cfa)	Area (ha)	Returns (cfa)
1. Local Sorghum + e Fert.	6.75	209250 (15)	7	217000 (15)	7	217000 (15)
2. Improved Cotton + Fert2	5	731000 (24)	4.5	657000 (24)	4.5	657000 (24)
3. Improved Maize + Fert2	1	5600 (30)	0.75	42000 (30)	0.65	36400 (30)
4. Improved Ground nut + Manure	-	-	0.75	37600 (60)	0.75	37600 (6)
5. Total	12.75	995250	13	953600	13	948000
Cert. Equ.		995250		921000		848000

NB : Fert. refers to small quantities of inorganic fertilizers applied on local sorghum and millet. Fert2 for sorghum are : 100 kg of complex cereal and 50 kg of urea.

Fert2 for cotton are 200 kg of complex cotton and 50 kg of urea. Manure is 5 t/ha. Land preparation technique is ridging for sorghum, cotton. Fert. for groundnut refers to 150 kg of complex cereal per hectare. 0 refers to coefficient of variation. r is the absolute risk aversion coefficient. Cert. Equ. is Certainty Equivalent is the risk-free return. It is the difference between the expected return and the risk premium.

Table 4. Short-Term Effects of Devaluation on the Profitability of Crop Technologies in the Sudano-Guinean Zone (With no Change in the Credit Policy and no Control of Cotton Area).

Crop technologies	Risk neutral (r = 0)		Risk averse (moderate) r = 2		Risk averse (strong) r = 3	
	Area (ha)	Returns (cfa)	Area (ha)	Returns (cfa)	Area (ha)	Returns (cfa)
1. Improved Sorghum	4	154400	5	193000	5	193000
+ Fert2		(15)		(16)		(16)
2. Improved Sorghum	1	63000	-	-	-	-
+ Fert2 + Manure		(40)				
3. Improved Cotton	5	730000	4.5	607500	4.5	607500
+ Fert2		(21)		(21)		(21)
4. Improved Maize +	5	250000	5	250000	4.5	228000
Fert2		(34)		(34)		(34)
5. Improved	-	-	0.5	28000	-	-
Groundnut + Fert				(30)		
6. Improved	-	-	-	-	0.75	46000
Groundnut +						(6)
Manure						
Total	15	1200000	15	1080000	14.75	1074000
Cert. Equ.		1200000		1055000		102000

NB : Fert2 for sorghum are : 100 kg of complex cereal and 50 kg of urea.
Fert2 for cotton are 200 kg of complex cotton and 50 kg of urea.
Manure is 5 t/ha. Land preparation technique is ridging for sorghum, cotton. Fert. for groundnut refers to 150 kg of complex cereal per hectare. () refers to coefficient of variation.

In summary, the supply of credit together with the lift of cotton input rationing after the devaluation will substantially increase farm income and demand for inorganic fertilizers. Farmers would use more inorganic fertilizers if credit availability is increased. The availability of credit to millet, maize, and groundnut is critical to the adoption of the improved technologies of these crops in the Sudano-Guinean zone.

c) Long-Term Effects of Devaluation on the Adaptation of New Technologies (Scenario 1, no Credit Policy, no Control of Cotton Area)

In the long term, when cotton area is not controlled and when prices of local cereals, maize and groundnut increase by 25%, the average farmer (moderate risk averse) would increase cotton area by 50% but would not adopt improved cultivars of sorghum combined with higher or moderate levels of inorganic fertilizers because of lower returns compared to cotton and maize (Table 5). The increase in farm income and demand for inorganic fertilizers would be 50% and 25%, due to higher prices of cereals and groundnut as the long-term effects of devaluation. The increase in local cereal prices would result from the substitution for the more expensive cereal imports of sorghum and millet. The development of local cereal processing and marketing devices could also facilitate this substitution.

d) Long-Term Effects of Devaluation on the Adoption of New Technologies (Scenario 1, Change in the Credit Policy and no Control of the Cotton Area)

When credit policy changes by providing non-subsidized credit to all crops, farmers would adopt improved cultivars of sorghum and groundnut in addition to cotton and maize. The total return from the increase in the use of inorganic fertilizers and other input through credit would increase by 95% and 200% due to the combined effect of higher cereal and groundnut prices and the credit to provide input (Table 6). The credit would increase the area cropped in maize from 0.75 ha to 5 ha. The devaluation alone through the increase in cereal prices would increase farm returns by only 20%.

Table 5. Long-Term Effects of Devaluation on the Profitability of Crop Technologies in the Sudano-Guinean Zone (Scenario 1, no Change in the Credit Policy and no Control of Cotton Area).

Crop technologies	Risk neutral (r = 0)		Risk averse (moderate) r = 2		Risk averse (strong) r = 3	
	Area (ha)	Returns (cfa)	Area (ha)	Returns (cfa)	Area (ha)	Returns (cfa)
1. Local Sorghum	7	166000 (13)	7	266000 (13)	4.75	184300 (13)
2. Local Millet + e Fert.	-	-	-	-	2	74000 (14)
3. Improved Cotton + Fert2	5	731000 (25)	4.5	657000 (25)	4.25	620500 (25)
4. Improved Maize + Fert2	1.5	122550 (22)	0.75	60750 (22)	-	-
5.Improved Groundnut + Fert	-	-	-	-	1	64000 (10)
6.Improved Groundnut	-	-	0.75	63000 (5)	0.75	63000 (5)
Total	13.5	1120000	13	1046000	12.75	1006000
Cert. Equ.		1120000		1003000		925000

NB : e Fert refers to small quantities of inorganic fertilizers applied on local sorghum and millet. Fert2 for sorghum are : 100 kg of complex cereal and 50 kg of urea. Fert2 for cotton are 200 kg of complex cotton and 50 kg of urea. Manure is 5 t/ha. Land preparation technique is ridging for sorghum, cotton. Fert. for groundnut refers to 150 kg of complex cereal per hectare. r refers to absolute risk aversion coefficient. Cert. Equ. refers to Certainty Equivalent which is the risk free expected returns. It is the difference between the expected return and the risk premium. () refers to the coefficient of variation.

Table 6. Long-Term Effects of Devaluation on the Profitability of Crop Technologies in the Sudano-Guinean Zone (Scenario 1, Change in the Credit Policy and no Control of Cotton Area).

Crop technologies	Risk neutral (r = 0)		Risk averse (moderate) r = 2		Risk averse (strong) r = 3	
	Area (ha)	Returns (cfa)	Area (ha)	Returns (cfa)	Area (ha)	Returns (cfa)
1. Local Sorghum + Fert2	4	208000 (8)	5	255000 (12)	5	255000 (8)
2. Improved Sorghum + Fert2 + Manure	0.75	79000 (30)	-	-	-	-
3. Improved Cotton + Fert2	5	674500 (25)	4.5	603000 (25)	4.5	60300 (25)
4. Improved Maize + Fert2	5	380500 (22)	5	380500 (22)	4.5	342000 (22)
5. Improved Groundnut + Fert	-	-	-	-	0.50	30000 (10)
6. Improved Groundnut + Manure	-	-	0.75	56250 (5)	0.75	63000 (5)
Total	14.75	1342000	15.25	1300000	15.25	1295000
Cert. Equ.		1342000				1283000

NB : Fert2 for sorghum are : 100 kg of complex cereal and 50 kg of urea. Fert2 for cotton are 200 kg of complex cotton and 50 kg of urea. Manure is 5 t/ha. Land preparation technique is ridging for sorghum, cotton. Fert. for groundnut refers to 150 kg of complex cereal per hectare. ( ) refers to coefficient of variation. r refers to the absolute risk aversion coefficient. Cert. Equ. refers to the certainty equivalent which is the risk free expected return. It is the difference between the expected return and the risk premium.

In summary, the combined impact of the long-term effects of the devaluation with credit encourage the adoption of improved cultivars of sorghum and groundnut with higher levels of inorganic and organic fertilizers and the increase in maize area. This leads to a substantial increase in farm returns. Improved cultivars of millet combined with higher levels of inorganic fertilizers are not adopted even with credit and increased prices because of the lower responses of improved millets to inorganic fertilizers.

e) Long-term Effects of Devaluation on the Adoption of New Technologies (Scenario 2, no Change in the Credit Policy and no Control of Cotton Area)

This scenario supposes a higher demand for local cereals and maize as processed cereals are demanded by urban population as food and feed with a corresponding increase in prices by 40%. Another alternative in the long term for the breeding program is to come up with sorghum cultivars more responsive to inorganic fertilizers. When no credit is allowed for other crops and when the cotton area control is lifted, the area of cotton increases by 50%. Total farm returns will increase by 40% and the demand for inorganic fertilizers increase by 25%. The same quantity of manure is used as its supply is inelastic and constrained by the number of livestock. In the modeling, farmers do not adopt improved cultivars of sorghum and millet combined with higher or moderate levels of inorganic fertilizer. The devaluation by itself does not lead to the adoption of improved cultivars of millet and sorghum in this zone (Table 7).

Table 7. Long-Term Effects of Devaluation on the Profitability of Crop Technologies in the Sudano-Guinean Zone (Scenario II, no Change in the Credit Policy and no Control of Cotton Area).

Crop technologies	Risk neutral (r = 0)		Risk averse (moderate) r = 2		Risk averse (strong) r = 3	
	Area (ha)	Returns (cfa)	Area (ha)	Returns (cfa)	Area (ha)	Returns (cfa)
1. Local Sorghum + e Fert.	6.75	300000 (12)	7	310000 (12)	7	310000 (12)
2. Improved Cotton + Fert2	5	730000 (25)	4.5	657000 (25)	4	548000 (12)
3. Improved Maize + Fert2	1.25	133500 (22)	0.75	80250 (22)		-
4. Improved Groundnut + Fert	-	-	-	-	1	81000 (10)
5. Improved Groundnut + Manure	-	-	0.75	79000 (5)	0.75	79000
Total	13	1163500	13	112625	12.75	1054000
Cert. Equ.		1163500		1083000		100500

NB : eFert is small quantities of inorganic fertilizer applied on local sorghum.
Fert2 for sorghum are : 100 kg of complex cereal and 50 kg of urea.
Fert2 for cotton are 200 kg of complex cotton and 50 kg of urea. Manure is 5 t/ha. Land preparation technique is ridging for sorghum, cotton. Fert. for groundnut refers to 150 kg of complex cereal per hectare. () refers to coefficient of variation. r refers to absolute risk aversion coefficient. Cert. Equ. refers to certainty equivalent which is the risk free expected return. It is the difference between the expected return and the risk premium.

f) Long-Term Effects of Devaluation on the Adoption of New Technologies (Scenario 2, Change in the Credit Policy and no Control of Cotton Area)

The last scenario is the change in credit policy combined with the lift on the control of the cotton area when local cereals, maize and groundnut prices change because of higher demand or if their yields increase by 40%. The farm returns would increase by 140% and 200% compared to the present practices. The long-term effects of devaluation will increase farm returns and the demand for inorganic fertilizers due to output price increase and supply of credit (Table 8). Improved cultivars of sorghum combined with higher levels of inorganic fertilizers are adopted by farmers on 5 ha and area cropped in maize also increases. Again, the supply of cereal credit drives the adoption of improved cultivars of sorghum combined with inorganic fertilizers.

2) The Sudanian Region - Impacts of New Technologies on Farm Incomes before Devaluation

The current technologies in the Sudanian region consist of local and improved cultivars of millet and sorghum, groundnut and cowpea with very low levels of inorganic and organic fertilizers. Local cultivars of millet and sorghum are not as responsive to inorganic fertilizers as improved cultivars. This has been a challenge for rural development projects where extension agents have been pressing farmers unsuccessfully to use high levels of inorganic fertilizers on local cultivars. When combined with higher or moderate levels of inorganic fertilizers, improved cultivars are profitable and are adopted according to the model results. The yields and returns of improved cultivar of sorghum combined with moderate levels of inorganic fertilizers increase by 40% and 90%, respectively, over local cultivars with the same levels of fertilization (Table 9). Ridging for millet and sorghum in use now by all farmers helps increase the responsiveness of sorghum combined with a low level of inorganic fertilizers (50 kg of urea per hectare) are adopted on 3 ha, according to the model results. Local cultivars of groundnut are increasingly being replaced by the early maturing improved cultivar of 47-10 which is combined with a low level of compound cereal fertilizer (50 kg/ha). Local cultivars of cowpea, TN8863, KN1, SUVITA2, are being adopted by farmers (Coulibaly, 1987), but with low levels of inorganic fertilizers. The improved cultivars of cowpea are early maturing and when combined with moderate levels of inorganic fertilizer and treated with insecticide they are profitable. According to the farm budget the improved cultivars of cowpea, when combined with moderate levels of inorganic fertilizers and a water-retention technique, are profitable. Improved cultivars of cowpea combined with compound fertilizers is cropped on 1 ha.

Table 8. Long-term Effects of Devaluation on the Profitability of crop Technologies in the Sudano-Guinean Zone of Mali (Scenario II, Change in the Credit Policy and no Control of Cotton Area).

Crop technologies	Risk neutral (r = 0)		Risk averse (moderate) r = 2		Risk averse (strong) r = 3	
	Area (ha)	Returns (cfa)	Area (ha)	Returns (cfa)	Area (ha)	Returns (cfa)
1. Local Sorghum + Fert2	3.5	240500 (8)	5	340000 (8)	4.5	309000 (8)
2. Improved Sorghum + Fert + Manure	0.75	91000 (30)	0.25	20000 (30)	-	-
3. Improved Cotton + Fert2	4.75	693500 (25)	4.5	657000 (25)	4.5	657000 (25)
4. Improved Maize + Fert2	5	535000 (22)	5	535000 (22)	5	535000 (22)
5. Improved Groundnut + Fert	1	81000 (10)	-	-	1	81000 (10)
6. Improved Groundnut + Manure	-	-	0.50	46500 (5)	-	-
Total	15	1640000	15	160000	15	158000
Cert. Equ.		1640000		1580000		1500000

NB: Fert2 for sorghum are : 100 kg of complex cereal and 50 kg of urea.
Fert2 for cotton are 200 kg of complex cotton and 50 kg of urea. Maize fertilizer levels are 150 kg urea and 100 kg of complex cereal, 150 kg of complex cereal are applied on groundnut. Land preparation technique is ridging for sorghum, cotton and maize and deep plowing for groundnut. Both techniques are water-conserving. () is the coefficient of variation. r refers to absolute risk aversion coefficient. Cert.

Equ. refers to certainty equivalent which is the risk free expected return. It is the difference between the expected return and the risk premium.

Table 9. Farm-Level Profitability of sorghum and Millet Technologies in the Sudanian Zone (Results from farm Budgeting before Devaluation).

Cultivars and fertilizers	Expected yields Kg/ha (9 years)	Percentage increase in yields	Expected returns CFA/ha (9 years)	Expected returns CFA/ha
A. Local cultivars				
1. Sorghum + e Fert.	560	(1) 48	25000	
2. Sorghum + Fert2	830		24000	
3. Millet + e Fert.	568	(3) 37	27300	
4. Millet + Fert2	780		24500	
B. Improved cultivars				
5. Sorghum + Fert1	1355	(2) 62	53000	(2) 120
6. Sorghum + Fert2	1358	(2) 63	49000	(2) 105
7. Millet + Fert1	1116	(4) 43	48000	(4) 95
8. Millet + Fert2	1105	(4) 41	40725	(4) 65

NB : The soil preparation technique is ridging.
Fert1 refers to 50 kg of complex cereal (15-15-15) plus 50 kg of urea (46N).
Fert2 refers to 100 kg of complex cereal and 50 kg of urea. The recommended level of fertilizer is used with local cultivars.

Impact of Devaluation on the Adoption of Improved Technologies

1) The Sudanian Zone

a) Short-Term Effects of Devaluation on the Adoption of Technologies (no Change in the Credit Policy)

A constraint in the Sudanian zone is the cash shortage at the beginning of the rainy season to purchase enough inorganic fertilizer, even if it is available. Most of the cash earned after sales is spent in mandatory taxes, and grain purchases for food with little cash left for inorganic fertilizer purchase. The devaluation further affects the purchasing power through higher prices for imported goods such as inorganic fertilizers. The short-term effects of the devaluation are the increase in input prices by 60%. The model results show that the increase in input costs has a negative impact on the adoption of improved sorghum and millet cultivars combined with moderate levels of inorganic fertilizers. No improved cultivars of sorghum or millet combined with inorganic fertilizers are adopted and farmers would allocate more land to local cultivars of millet combined with small quantities of inorganic fertilizer (Table 10).

Local cultivars of millet are less demanding in nutrients. Despite the increase in input prices, farmers would still continue using some improved early-maturing cultivars of cowpeas combined with low to moderate levels of phosphate fertilizer and deep plowing.

Table 10. Short-Term Effects of Devaluation on the Profitability of Crop Technologies in the Sudanian Zone (No Change in the Credit Policy).

Crop technologies	Risk neutral (r = 0)		Risk averse (moderate) r = 2		Risk averse (strong) r = 3	
	Area (ha)	Returns (cfa)	Area (ha)	Returns (cfa)	Area (ha)	Returns (cfa)
1. Improved Sorghum + Fert2	1.25	62500 (28)	-	-	-	-
2. Local Millet + e Fert.	12.5	340000 (17)	12	324000 (17)	11	297000 (17)
3. Local Groundnut + Fert + dp	-	-	1	45000 (13)	1.25	56260 (13)
4. Improved Cowpea + Fert2	1.5	124500 (19)	-	-	1	83000 (15)
5. Improved Cowpea + Fert + ur	-		1.75	145000 (16)	0.75	70550 (16)
Total	15.25	527000	14.75	514000	14	507000
Cert. Equ.		527000		502000		480000

NB : e Fert refers to small quantities of inorganic fertilizers applied on local sorghum and millet.

Fert1 refers to only 50 kg of urea applied on improved cultivars. Ridging is applied to sorghum and millet.

Fert for groundnut refers to 100 kg of complex cereal per hectare.

() refers to coefficient of variation. dp refers to depp plowing, a common soil preparation/Water retention technique for groundnut and cowpea. dp refers to depp plowing. tr refers to tied ridging. dpr refers to deep plowing followed by ridging. r refers to absolute risk aversion coefficient. Cert. Equ. refers to certainty equivalent which is the risk free expected return. It is the difference between the expected return and the risk premium.

The devaluation would decrease the expected farm incomes by 10% and the demand in inorganic fertilizers by 70% due to increased input prices following devaluation.

b) Short-Run Effects of Devaluation and New Technologies (with Changes in Credit Policy)

The model results show that the moderate risk averse farmer would adopt improved cultivars of millet and sorghum with a moderate level of inorganic fertilizers when credit is made available (see Table 11) to solve the liquidity constraint problem. Ridging is still used as the water conservation/soil preparation technique as practiced now on-farm. Improved groundnut and cowpeas combined with phosphate fertilizer and deep plowing are cropped, respectively, on 3 and 2.5 ha. The farm income would increase by 48%. The area cropped would decrease from 13.5 ha under the present practice to 13 ha with more use of the inorganic fertilizers.

c) Long-Term Effects of Devaluation on the Adoption of New Technologies (no Credit Policy)

As in the Sudano-Guinean region, the long-term effects of devaluation are assessed through two scenarios when the crop prices increase by 25% and 40% due to higher demand in the long term. Alternatively, more inorganic fertilizer responsive cultivars could be made available through the research programs in the long term.

With an increase in crop prices by 25%, the average farmer would choose the same crop activities except the improved sorghum, which will be combined with only phosphate fertilizers instead of the mix of compound fertilizer and urea (Table 12). Urea is riskier compared to the phosphate-based fertilizer when there is not enough moisture and, therefore, has been substituted to an increase in the level of compound fertilizers up to 100 kg/ha from 50 kg/ha. The farm income and inorganic fertilizer demand increase, respectively, by 75% and 300% due to the long -term effects of devaluation when compared with the present practices. No credit is necessary for the adoption of improved cultivars. The increase in the price makes the improved cultivars very attractive.

Table 11. Short-Term Effects of Devaluation on the Profitability of Crop Technologies in the Sudanian Zone (Change in the Credit Policy).

Crop technologies	Risk neutral (r = 0)		Risk averse (moderate) r = 2		Risk averse (strong) r = 3	
	Area (ha)	Returns (cfa)	Area (ha)	Returns (cfa)	Area (ha)	Returns (cfa)
1. Improved Sorghum +	3	150000 (28)	2.5	127500 (23)	1.5	72000 (28)
2. Improved Millet + Fert1	5	230000 (24)	5	230000 (21)	6.25	250000 (24)
3. Improved Sorghum + Fert3	-	-	5	-	0.25	10000 (33)
4. Improved Ground-nut + Fert + dp	3	273000 (9)		273000 (9)	3	273000 (9)
5. Improved Cowpea +	2.5	189000 (19)	2.5	189000 (19)	2.5	189000 (19)
6. Improved Cowpea + Fert + tr	-	-	-	-	0.25	20250 (9)
Total	13.5	842000	13	819000	13.75	814000
Cert. Equ.		842000		800000		785000

NB : eFert refers to small quantities of inorganic fertilizers applied on local sorghum and millet.

Fert1 refers to only 50 kg of urea applied on improved cultivars. Ridging is applied to sorghum and millet. Fert for groundnut refers to 100 kg of complex cereal per hectare.

() refers to the coefficient of variation. r refers to relative risk aversion coefficient. tr refers to tied ridging. dpr refers to deep plowing followed by ridging. Cert. Equ. is the certainty equivalent which is the risk free expected return. It is the difference between the expected return and the risk premium.

Table 12. Long-term Effects of Devaluation on the Profitability of Crop Technologies in the Sudanian Zone (no Change in the Credit Policy).

Crop technologies	Risk neutral (r = 0)		Risk averse (moderate) r = 2		Risk averse (strong) r = 3	
	Area (ha)	Returns (cfa)	Area (ha)	Returns (cfa)	Area (ha)	Returns (cfa)
1. Improved Sorghum	4	244000 (24)	-	-	-	-
2. Improved Sorghum + Fert3	-	-	.5	26000 (26)	3	156000 (26)
3. Improved Millet + Fert1	5	285000 (14)	7.5	427500 (14)	5	285000 (14)
4. Improved Ground-nut + Fert +dp	2.5	255000 (10)	3	306000 (10)	3	306000 (10)
5. Improved Cowpea +	2.5	237500 (19)	0.5	45000 (19)	2.5	237500 (19)
6. Improved Cowpea + Fert + rdg	-	-	2	190000 (19)	-	-
Total	13.	10215000	13.5	994500	13.5	984500
Cert. Equ.	5	1021500		965000		950000

NB : eFert refers to small quantities of inorganic fertilizers applied on local sorghum and millet. Fert1 refers to only 50 kg of urea and 50 kg of compound fertilizers applied on improved cultivars of millet and sorghum. Fert3 refers to 100 kg of compound fertilizers only. Ridging is applied to sorghum and millet. Fert. for groundnut is 100 kg of complex cereal per hectare. ( ) refers to coefficient of variation. r refers to relative risk aversion coefficient. dp refers to deep plowing, a common soil preparation/water retention technique for groundnut and cowpea.
dp refers to deep plowing. tr refers to tied ridging. Cert. Equ. is the certainty equivalent which is the risk free expected return. It is the difference between the expected return and the risk premium.

d) Long-Term Effects of Devaluation on the Adoption of New Technologies (with Change in Credit Policy)

When the credit policy changes, the same cropping activities are adopted by farmers, but more area would be allocated to improved millet combined with moderate levels of inorganic fertilizers. The improved cultivars of millet combined with inorganic fertilizers has a much lower coefficient of variation in returns (less risk) and therefore is more adapted to harsh agroecological conditions. The change in the credit policy would slightly decrease the farm income compared to the precedent scenario because of the interest rate charged on the credit (10%). The increase in crop prices by 25% is enough to substantially increase farm returns without credit and the demand for inorganic fertilizers remains unchanged (Table 13).

Conclusions

The differences between the cotton technological success and the slower introduction of improved technologies for millet and sorghum are the more favorable natural and institutional environments compared to the low rainfall and poor soil fertility in the Sudanian region. With more rainfall, inorganic fertilizers are less risky. With guaranteed prices and credit for cotton, the technologies associated have a better chance to be quickly adopted.

The devaluation by itself is not enough to encourage farmers to adopt improved cultivars of millet, sorghum and groundnut in the short term in either zone. It needs to be combined with some credit policy to solve the liquidity problem faced by most of the farmers. In the long run, the credit policy may not be necessary to encourage adoption in the Sudanian zone if the demand for millet, sorghum, cowpea and maize increases due to the competitiveness of these commodities. Both the historic exchange rate policies and the specific maize and cotton policies reduced the relative profitability of sorghum and millet. This situation is changing with the increasing availability of a range of sorghum and millet technologies and the structural adjustment policies.

Table 13. Long-term Effects of Devaluation on the Profitability of Crop Technologies in the Sudanian Zone (Change in the Credit Policy).

Crop technologies	Risk neutral (r = 0)		Risk averse (moderate) r = 2		Risk averse (strong) r = 3	
	Area (ha)	Returns (cfa)	Area (ha)	Returns (cfa)	Area (ha)	Returns (cfa)
1. Improved Sorghum +	8	486000 (24)	1	52000 (26)	-	153000 (26)
2. Improved Sorghum + Fert3	-	-	7	392000 (14)	3	285000 (14)
3. Improved Millet + Fert1	4.25	241000 (14)	3	306000 (10)	5	306000 (10)
4. Improved Groundnut + Fert +dp	0.65	65000 (10)	0.5	45000 (19)	3	232500 (19)
5. Improved Cowpea +	2.5	232500 (19)	2	190000 (19)	2.5	-
6. Improved Cowpea + Fert + rdg	-	-	13.5	985000	-	976500
Total	15.5	1024500		950000	13.5	944000
Cert. Equ.		1024500				

NB : eFert refers to small quantities of inorganic fertilizers applied on local sorghum and millet.

Fert1 refers only to 50 kg of urea and 50 kg of compound fertilizers applied on improved cultivars of millet and sorghum.

Fert3 refers to 100 kg of compound fertilizers only. Ridging is applied to sorghum and millet.

Fert for groundnut refers to 100 kg of complex cereal per hectare.

( ) refers to the coefficient of variation. r refers to absolute risk aversion coefficient. Cert. Equ. refers to the certainty equivalent which is the risk free expected return. It is the difference between the expected return and the risk premium.

Technologies to maintain the sustainability of the cropping system have to address soil fertility and water availability in the Sudanian zone and the soil fertility and stagnant yields in the Sudano-Guinean zone. To be adopted by farmers, these new technologies need to be profitable. Improved cultivars of sorghum, cotton, and maize combined with higher levels of inorganic fertilizers are profitable in the Sudano-Guinean zone where soil and rainfall are more favorable. Improved millet, sorghum, groundnut and cowpea cultivars with moderate levels of inorganic fertilizers combined with water retention are potential technologies which will be adopted by farmers. For adoption of the cereals to take place, input-tied credit needs to be provided to enable the purchase of inorganic fertilizers and improved seeds.

In the Sudano-Guinean zone, the introduction of improved technologies, i.e., new cultivars plus inorganic and organic fertilizers, have been more successful for cotton and maize than local cereals. Structural adjustment (devaluation) was expected to facilitate the introduction of new technologies for domestic cereals. This effect results from the higher prices of domestic cereals as they substitute for the more expensive imported cereals. Unfortunately, the short-term effect of devaluation is a decrease in the profitability of domestic cereals since the imported input costs for chemicals are increasing faster in the short run than increases in prices of domestic cereals. Moreover, the new cereal technologies require higher consumption levels of imported inorganic fertilizers. In the long run, as the domestic cereals substitute more for the imported cereals (rice and wheat), the domestic cereals price is expected to further increase, making cereals more profitable. In the short run, improved but not necessarily subsidized credit policies will be necessary to get the improved cereals and associated technologies adopted by farmers, according to model results.

Devaluation has a positive effect on farm incomes and the introduction of new technologies in the Sudano-Guinean zone. As an export crop, cotton revenues will increase and therefore benefit the overall farm investment in new technologies. In the long term, farm incomes will increase more following the increase in locally produced cereal prices or, alternatively, to the availability from the breeding programs of more inorganic fertilizer-responsive cultivars. But even in the long run, adoption of improved cereals requires credit as the price increase will not be enough incentive for adopting improved cereal cultivars.

The devaluation slightly decreases farm incomes in the Sudanian region in the short term because of the lack of export crops. Cowpea has some future potential as an export crop, but needs to be sustained through the development of storage techniques, the organization of the input industries (especially for seed and fertilizer), and the development of product marketing institutions. The devaluation will have positive effects on farm incomes in this region in the long term when domestic cereal prices increase or if more yield-responsive cultivars of millet and sorghum are made available from the breeding programs. In the short run, higher prices of inorganic fertilizers is a disincentive for the adoption of new cereal technologies unless some credit is provided.

The introduction of improved technologies, new cultivars, and inorganic and organic fertilizers have been more successful for cotton and maize than local cereals. More success is expected during the next decade as the introduction of improved cultivars of sorghum, millet, cowpea and groundnut is taking off and improved economic policies with less of an anti-agriculture orientation are being pursued. The improved economic policies and the pressure for more food production will increase the demand for purchased inputs, especially inorganic fertilizers. The major constraint here is the ability of the purchased inputs, especially inorganic fertilizers. To respond to this increased demand.

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CHAPTER II

Technology Options :
Food Grains

Maize Improvement and Technology Options for its Production in the West and Central Africa Savannas

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Abstract

Within the past 25 years, maize (*Zea mays* L.) has evolved from a predominantly forest food-grain crop of limited yield potential to a productive food and cash crop of the West and Central Africa savannas. This has been made possible through several regional, international, bilateral or national initiatives in research, and/or development spurred largely by the continental droughts of the early 1970s and the subsequent declining per capita food production.

The development of appropriate production technologies, especially improved and adapted varieties, was the prime mover of the monumental maize spread in the West Africa grainary. The technologies were progressively refined to make them more responsive to the changing production environment, notably crop productivity-related constraints, producer/consumer preferences, socio-economic as well as policy-related considerations. The tailoring of maize to the savanna ecosystem has, in step-wise cumulative manner, reinforced the crop through the development of several varieties resistant to or tolerant of several diseases and stresses. The varieties are of contrasting characteristics to adequately exploit the opportunities in the prevailing or evolving farming systems and the socio-industrial landscape. Parallel research activities were carried out to determine management practices that promote the expression of the genetic potential of the varieties.

The progression of maize cultivation in the sub-region, through extensification and/or intensification, has exposed the vulnerability of the subregion to environmental degradation and probable decline of farm productivity. The question of sustainability of profitable maize production calls for a profound re-thinking of research strategy as well as integrated approach to rural development. The implication of these far-reaching issues on the technicalities of technology generation is discussed.

Résumé

Au cours des 25 dernières années, le maïs (Zea mays L.) a évolué, d'un statut de culture vivrière essentiellement exploitée en zone forestière avec un potentiel de rendement limité, à un état de culture vivrière et de rente productive dans les savanes d'Afrique Centrale et Occidentale. Cette évolution a pu se faire grâce à plusieurs programmes régionaux, internationaux, bilatéraux ou nationaux de recherche et/ou de développement essentiellement suscités par les sécheresses continentales du début des années 70 et par la baisse subséquente de la production vivrière per capita.

La mise au point de technologies de production appropriées, de variétés améliorées et adaptées en particulier, a constitué l'élément fondamental de l'extension considérable de la production du maïs pour remplir les greniers de l'Afrique Occidentale. Les technologies ont été progressivement peaufinées pour répondre mieux au changement de l'environnement de production, surtout aux contraintes liées à la productivité des cultures, aux préférences des producteurs et des consommateurs, aux conditions soicoéconomiques et d'ordre politique. L'adaptation de la production du maïs à l'écosystème de savane a, en même temps, favorisé l'adoption de la culture grâce à la mise au point de plusieurs variétés résistantes ou tolérantes àplusieurs maladies et stress. Ces variétés comportent des caractéristiques diversifiées de façon à bien exploiter les conditions qui se présentent dans les systèmes culturaux prédominants ou en évolution et dans le paysage socio-industriel. Des activités de recherche parallèles ont été menées avec pour objectif de déterminer les pratiques de gestion susceptibles de promouvoir l'expression du potentiel génétique des variétés.

La progression de la culture du maïs dans la sous-région (extensification et/ou intensification) a exposé la sous région vulnérable à la dégradation environnementale et à une régression probable de la productivité agricole. La question de la durabilité d'une production rentable de maïs appelle une sérieuse révision de la stratégie de recherche ainsi qu'une approche intégrée relative au développement rural. Cette communication examine l'implication de ces questions de grande portée sur la technicité de la mise au point de technologies.

Introduction

Although maize (*Zea mays* L.) was introduced into West Africa in the mid 1500s through both the coastal and trans-Saharan routes, it remained merely a compound household delicacy in the savanna belt until about 25 years ago. On the other hand, in the coastal rainforest zone, maize has played a major role in the evolution of the prevalent root-crop based and other cropping systems. Landraces evolved through adaptation to the humid, low solar-radiation environment assisted by selection by subsistence farmers for acceptable grain types for local dishes. With 80% of the production in the region being used for direct human consumption, maize is principally a food crop. Per capita consumption varies from 1kg/year in Niger, a Sahelian country, to 87 kg/year in Benin on the Atlantic coast (CIMMYT, 1994). Therefore, in many countries in the region, maize plays an important and comparable role on the socio-cultural life as in the Eastern and Southern Africa; Mexico, Central America, and the Caribbean; and Andean Region and South America.

Maize has become a popular crop in West and Central Africa because it is relatively easy to grow, store, transport, mill and convert to various dishes. It has expanded faster than the major traditional cereals, sorghum and millet. During the period 1983-1992, the annual growth rate of maize area was 2.7% for the region (CIMMYT, 1994), with several countries having values above the regional average, namely: Burkina Faso (7.4%), Guinea (9.4%), Mali (6.6%), Nigeria (3.5%), Senegal (3.0%), Togo (3.1%), and Zaire (5.5%). Average regional yield is, however, the lowest in the world (Table 1), although some countries have made some remarkable progress. These include Burkina Faso, Cameroon, Côte d'Ivoire, Ghana, Nigeria and Togo with percent annual

Table 1. Maize production data for West and Central Africa and other regions/groupings of the world[a]

	West and Central Africa	Eastern & Southern Africa	Less developed countries[b]	Developed countries	World
West and Central Africa	279.8	255.6	4295.5	847.8[b]	5479
Estimated growth of population, 1991-2000(%/year)	2.9	3.2 1.8	0.6[b]	1.5	
Maize area harvested, 1986-88 (000ha)	5295.0	9871.0	81813.0	34258	127771
Maize area harvested, 1990-92 (000ha)	6456.0	9588.0	83630.0	36327	129804
Maize production, 1986-88 (000t)	5080.0	13662.0	182732.0	213712	450910
Maize production, 1990-92 (000t)	6172.0	11523.0	213062.0	252254[b]	498857
Maize yield, 1961-65 (t/ha)	0.8	1.0	1.4	3.5	2.2
Maize yield, 1986-88 (t/ha)	1.0	1.4	2.2	6.2	3.5
Maize yield, 1990-92 (t/ha)	1.0	1.2	2.5	6.9[b]	3.8
Growth rate of maize area, 1973-82(%/year)	-0.1	-0.3	0.6	1.2[b]	0.7
Growth rate of maize area, 1983-92(%/year)	2.7	1.5	1.1	0.5[b]	0.6
Growth rate of maize production, 1973-82(%/year)	-0.5	1.7	3.7	5.1[b]	4.3
Growth rate of maize production, 1983-92(%/year)	4.1	0.9	3.2	3.2[b]	2.5
Growth rate of maize yield, 1973-82(%/year)	-0.4	2.0	3.1	3.9[b]	3.6
Growth rate of maize yield, 1983-92(%/year)	1.5	2.0	2.1	2.7[b]	1.8
Percent of maize used for direct human consumption	80.0	85.0	40.0	14[b]	21

[a]: Source: 1. CIMMYT, 1981; 2. CIMMYT, 1990; 3. CIMMYT, 1994

[b]: Data for Eastern Europe and former Soviet Union are not included

growth rate of maize yield (1982-92) of 9.7, 4.1, 1.8, 8.1, 1.8 and 2.9%, respectively, compared to the 1.5% regional average.
This rather promising trend of increased maize production is principally attributable to the shifting of maize production from its traditional rainforest belt to the savanna. The factors responsible for this; the perceived concerns for sustainability; and the research options for addressing them are discussed in this paper.

The Savanna and Maize Production

The Environment

The West and Central Africa savanna is not a homogeneous eco-climatic belt. The savanna spans from the northern fringe of the rainforest in the south to the arable southern edge of the Sahara, often described as the Sahel. It is therefore a continuum which is undergoing dynamic changes intricately linked with global climatic fluctuations as influenced by human activities. In the period, 1965-1985, the isohyetes in the region had reduced in amplitude by 100-250 mm; the 100 mm in the northern and the 250 mm in the southern limits (Pieri, 1989). Since 1968, the savanna has witnessed exceptional droughts which nobody could have predicted; rainfall deficit in Senegal (1968-1982) has varied from 25 to 33% of the pre-1968, 30-year average (Pieri, 1989). The semi-arid zone of the West African savanna is a product of delicate equilibrium between man, the soil, vegetation and the climate; the latter is characterized by a long dry season and a single rainfall season.

High insolation and more reliable monomodal rainfall distribution contribute to high yields of the short to medium duration annual crops in the northern Guinea savanna. Lower night temperature also promotes dry matter accumulation and partitioning leading to higher harvest index (Kassam *et al.*, 1975). But the response of crop plants to the high solar radiation and favorable temperature depends on other environmental factors, such as rainfall, soil nutrients and water, weed competition, crop cultivar, crop health, input level, and proper management of the vegetation.

The severity of annual weed infestation in the moist savanna zone of West Africa follows the rainfall pattern and, therefore, weed pressure generally decreases as one moves from the derived savanna to the northern Guinea savanna zone (Tian *et al.*, 1994). Exceptions to this pattern are *Imperata cylindrica* in the derived savanna and southern Guinea savanna and the parasitic weed *Striga hermonthica* in the northern Guinea savanna. *Striga* spp. are widely distributed root parasites that derive their mineral nutrients, water and carbohydrates from their wide range of hosts, including major staple crops (sorghum, pearl millet, finger millet, maize, fonio, sugar cane, cowpea) and natural pasture (Emechebe *et al.*, 1994). The *Striga* problem threatens the livelihood of the small-scale and resource-poor farmers (who constitute about 80% of the farming population) because, among other reasons, it is exacerbated in degraded soils of poor fertility and low moisture retention capacity

In addition, the savanna megazone is affected by several other crop production constraints, both physical (especially erratic rainfall and drought) and biotic (insect pests and diseases). Wind erosion is remarkable at the beginning of the cropping season, particularly in areas where annual rainfall is less than 600 mm and on bare soils.

The Phenomenal Role of Maize

Until the second half of the century, government efforts to develop agricultural production in West Africa were devoted to adapted cash crops of comparative yield advantage to feed the colonial empire's overseas' industries. These included perennial crops like cacao, oil palm and rubber for the forest ecology and annual crops, essentially groundnuts and cotton, for the savanna. This policy was continued even after independence in order to generate surplus economy for the individual country's development. Increased food production for the rapidly increasing population was taken for granted through the traditional bush-fallow, subsistence farming.

The initiation or intensification of maize research activities at national levels in the mid to late 1960s in each West African country was enhanced by the setting up of projects run and funded by foreign agencies. Perhaps the most significant is the Joint Project 26 (Africa's Major Cereals Project) funded by the USAID with the West African headquarters in Nigeria. The Project was under the aegis of the Scientific, Technical and Research Commission of the Organization of African Unity (OAU-STRC JP 26). Research efforts under this project based at Moor Plantation, Ibadan and with significant outstation activities at Mokwa and Samaru (in the southern and northern Guinea savanna zones of Nigeria, respectively) resulted in the development of NCA and NCB (Nigeria Composites A and B) synthesized from various maize germplasm types from the Caribbean, Tropical America and West Africa using the comprehensive maize breeding system (Eberhart, 1967). Parallel efforts by CIRAD/IRAT expatriate researchers at the same time frame in francophone countries, notably, Benin and Côte d'Ivoire, led to the development of such germplasm as CJB. Joint Project 26 in 1968 initiated and coordinated a West Africa Uniform Maize Trial comprising elite germplasm from the region's maize breeding programs —anglophone (principally Nigeria and Ghana) and francophone (Benin and Côte d'Ivoire).

Results of the multilocation regional West Africa Uniform Maize Trials from 1968 to 1972 demonstrated the yield superiority of maize over the region's traditional cereals, sorghum and millet. It also confirmed the results from country-wide multilocation trials, such as the Nigeria's National Zonal Trials that, in general, a maize variety produces 30-75% more yield in the savanna than in the forest zone (Fajemisin *et al.*, 1976). This view has been investigated, validated and scientifically rationalized by Kassam *et al.*, (1975) based at the Institute for Agricultural Research, Ahmadu Bello University (IAR-ABU), Samaru, Nigeria. Agronomic and rural socio-economic studies by IAR-ABU scientists reinforced genetic improvement for a pivotal role of maize in the savanna. The establishment of IITA and its subsequent development of the high yielding improved germplasm, TZB (based on NCA, and NCB) which, together with materials from CIMMYT's international trials provided varieties for production in the various countries across the West African savanna.

In general, in the West and Central African countries, institutional support for maize in the mid 1970s and the 1980s has contributed largely to maize diffusion. This is because maize was seen as a means to increase cereal productivity and to improve the national food stock. The strategy however varies from country to country and markedly between the francophone and the anglophone groups.

In the francophone countries from Senegal in the west to Cameroon in the east, institutional support for maize was through the cotton growing companies (Fusillier *et al.*, 1994). Through the impetus of the French company, "Compagnie Française de Développement Textile (CFDT)", and later the sister national companies progressively created from the 1960s, cotton production has developed remarkably in the African savanna (700-1400mm of rainfall). The cotton company imposed maize as a rotation crop to complement cotton and as an intensification effort for food crop production by the cotton growers. In addition to the provision of improved seed, fertilizer and herbicide in kind, maize farmers benefited from the mechanization support for cotton as well as training in improved crop management techniques (Fusillier *et al.*, 1994). For example, being the privileged rotation crop with cotton, area extension was made possible through mechanization and animal traction. The use of fertilizer in maize is well developed in the cotton zone. Millet and sorghum fields of the cotton growers almost never received fertilizer; on the other hand, the percentage of maize fields fertilized varied from 20-50% in Senegal to 50-70% in Mali (Fusillier *et al.*, 1994). Fertilized area (maize) in Mali, increased from 10,000ha in 1981 to 70,000ha in 1992. The better soils were often reserved for maize and the poorer ones for sorghum and millet. The utilization of improved maize varieties also contributed to reinforce the superiority of maize over sorghum. With its high yield potential, clearly superior to sorghum, maize allows a higher labour productivity even though more demanding.

Maize diffusion into the savanna in Nigeria was made possible largely through food production awareness campaigns such as the National Accelerated Food Production Project (NAFPP) and Operation Feed the Nation (OFN) and through the World Bank-assisted Agricultural Development Projects (ADPs). The ADPs based in northern Nigeria introduced TZB to the savanna farmers and demonstrated how to obtain high yield using fertilizers and other crop management practices. Farmers found that maize gave them much higher returns than other cash crops and they began to expand production rapidly. Market demand was in the south with maize as food, basic ingredient in brewery, and animal feeds to absorb increased production from the north. Good road networks, distribution of subsidized fertilizer and the development of input-responsive varieties and hybrids radically altered the circumstances of maize in the Nigerian moist savanna from a minor crop in the 1970s to a major food crop in most villages by 1989 and as an important cash crop in some two-thirds of maize growers (IITA, 1990).

The spread of maize in the West and Central African moist savanna was phenomenal in the 1980s. This has translated into the remarkably high annual growth rate of production in the period 1983-1992 in the following countries; Burkina Faso(17.1%), Ghana(8.3%) Guinea(7.6%), Mali(7.5%), Nigeria(5.3%) and Togo(6.1%) and a regional average of 4.1% compared to a 0.9% average for the Eastern and Southern Africa region over the same period (CIMMYT, 1994). It is important to note that many of these front-line maize producers enjoyed striking annual growth rates of maize yield (1.8-9.7%) over the same period (1983-1992). This demonstrates that the increased production is not just as a result of increased area; it is accompanied by clear element of intensification.

We are indeed at the threshold of taking the West and Central Africa region out of decades of chronic low yields. The latest (1990-1992) statistics show that many countries in the region have exceeded long-standing 1.0t/ha regional average. They are Burkina Faso (1.5t/ha), Cameroon (1.8t/ha), Ghana (1.3t/ha), Mali (1.3t/ha), Nigeria (1.2t/ha) and Senegal (1.1t/ha).The rate of increase of maize production in the savanna over the period 1974/77 to 1989/91 is 8.6% in the savanna which is about twice as much as the rate (4.7%) in the coastal; average figure for sorghum and millet in the same period is 3.3%.

Maize Improvement Initiatives

The development of the right crop production technology, particularly well adapted varieties good enough to attract farmers' commitment to invest in maize production, is a result of decades of cumulative research initiatives which built on farmers' selection efforts. Highlights of this evolutionary process will be presented under three broad headings.

Evolution of landraces

The lower yield potential of the African lowland tropical maize is a consequence of centuries of natural selection and by subsistence farmers for better adaptation to the biophysical environment as well as to fit the farmers' cropping systems and food characteristics. It is, therefore, not surprising that the product had a vigorous leafy growth which enabled the crop to compete better with weeds and to compensate for leaf damage by diseases and insects prevalent in the humid rainforest. The ears evolved with heavy husk cover and the stem was conspicuously strong to withstand heavy storm and to provide resistance to stalk rots. Several landraces evolved in response to the specific selections for ethnic or village preferences, particularly in terms of grain color (white, yellow, purple, red) and grain texture (soft/hard, floury/flint and other variations).

In West Africa, little maize improvement work was done before 1949 when the tropical maize rust (*Puccinia polysora* Underw.) found its way to the region from Central America. Local varieties were devastated because they had very low levels of resistance. Over 400 years of selection in the absence of rust had led to the erosion of resistance genes that might have existed in maize when it was freshly introduced into coastal West Africa.

The establishment of the West African Maize Rust Research Unit (WAMRRU) in Moor Plantation, Ibadan, Nigeria introduced and screened many foreign varieties. These introduced varieties, however, did not make any impact on the local farmers because their grain-types were found unacceptable to the consumers. By 1959, the rust epidemic had subsided. This is perhaps due to the effect of natural and farmers' selection on local germplasm which contained some resistance genes at low frequency (Cammack, 1961). WAMRRU was thereafter disbanded. A new set of landraces had evolved with appreciable level of enduring resistance to maize rust.

Pre-IARCs' improvement efforts

The gap between the yields of West and Central African maize farmers and those of farmers in the other regions of the world widened before and after the continental rust epidemic. The differences in growing conditions in the tropical lowlands, which typify most of West and Central Africa, from those of the high-yield temperate zone of the

United States Corn Belt, for instance, make it difficult to transfer improved germplasm directly from the temperate to non-temperate environments.

However, in 1966, maize breeding in West Africa received a further boost when, in an attempt to address the declining per capita food production in Africa, the Scientific and Technical Research Commission of the Organization of African Unity (OAU-STRC) launched, with USAID funding, a Major Cereals Project (JP26) for the improvement of the traditional/popular cereal staple food crops —sorghum, millet and maize. The Federal Department of Agricultural Research in Moor Plantation, Ibadan, Nigeria hosted the maize component of the Project. By transferring breeding techniques from the temperate zone and modifying them to address the specific problem of the tropical maize, the so-called comprehensive breeding system was utilized to synthesize two genetically wide-based composites —Nigerian Composites A and B (NCA and NCB) in 1968. Evaluation of these composites in the West African Uniform Maize Trials, coordinated by JP26, and conducted by national programs in the region (1969-1972) proved the superiority and adaptability of NCA and NCB. Seeds of these germplasm types were requested by maize breeders in the various countries for recurrent selection and/or for further tests.

Improving and stabilizing yield potential

IITA began its maize breeding activities at Ibadan in 1970. NCA and NCB were taken as the starting point for population improvement. These composites underwent further selection for higher grain yield; improved plant type (a short, strong stalk with low ear placement); resistance to various diseases and insect pests; and heat tolerance at the seedling stage (IITA, 1992). By 1972, the populations (NCA, NCB) had been changed substantially through intensive selection and the introgression of new germplasm. In recognition of their altered character, the two materials were given the IITA germplasm designation, TZA and TZB. By 1974, it was clear that TZB performed better than TZA. For that reason and because no heterosis could be detected in crosses between the two populations, they were merged, with the new version of TZB containing about 25% TZA.

At about the same period, early to mid 1970s, CIMMYT international maize testing program was put in place and there were simultaneous intensive efforts to restructure maize germplasm development to fit the developing world's major growing environments. National maize research programs identified promising CIMMYT germplasm and requested for seed for further testing. IITA created another population, TZPB, from "Planta Baja" materials developed by CIMMYT in Mexico. TZPB gave high yields, especially in the forest zone; and has softer, dent grains than the flinty TZB.

With the availability of improved maize germplasm from the international centers in the mid 1970s to the region's national programs, the maize streak virus (MSV) surfaced as a potent, African-specific, yield-destabilizing factor. IITA therefore devoted the second half of the 1970s to intensive study of the disease, the biology of MSV vector, the *Cicadulina* leaf hopper, and its artificial rearing and to the development of a simple, efficient, infestation technique. Genetic resistance to MSV was incorporated into adapted germplasm (Efron *et al.*, 1989). A close working relationship between IITA and NARS was initiated in 1979 and intensified in the early 1980s to collaboratively evaluate breeding populations and varieties in international testings. This permitted the development of improved maize populations and varieties and the validation of the durability of the streak resistance across sites, countries, ecologies and years. From 1980 to 1987, CIMMYT based a maize breeder at IITA, Ibadan to incorporate streak resistance, largely through backcrossing, into varieties that were otherwise well adapted to the African environments.

The overall goal of the IITA Maize Research Program was to develop varieties that will help the West and Central African farmers to reduce the risks associated with intensive maize production. The strategy involves breeding for durable resistance to African-specific pests, diseases and stress because IITA was concerned about yield stability as much as about increasing yields (Fajemisin *et al.*, 1985). The principal constraints are downy mildew, stem and ear borers, storage insects and *Striga*. Another cardinal issue in IARCs' (IITA and CIMMYT) strategy was to develop distinct germplasm complexes adapted to different agroecosystems rather than search for broad-based adaptation. In the early 1980s, at the request and with the support of the Federal Government of Nigeria, IITA embarked on the development of hybrid maize adapted to lowland tropical environment. In turn, the availability of hybrid maize has led to the establishment of private seed companies in Nigeria.

The establishment in 1977 of SAFGRAD, another intervention by the Organization of African Unity, in response to the recurrent droughts of the late 1960s and early 1970s, provided a focus for the development of maize, especially for the subhumid zones of Africa. It also served as a vehicle for collaboration among national maize program scientists across the region (across language groups —francophone, anglophone and lusophone, etc.) on constraints to maize production and on approaches to resolving them. IITA was identified by the OAU and the donor (USAID) as the contractor for SAFGRAD's project on maize and cowpea while ICRISAT was for sorghum and millet. The IITA-SAFGRAD scientists, through resident research in Burkina Faso and in collaboration with NARS in the region, developed intermediate, early and extra-early maize germplasm. They also identified constraints to effective crop management (especially for the semi-arid zone) and investigated several agronomic options for increased and sustainable maize yield.

The second phase of SAFGRAD (1987-1993) was equally important (Fajemisin, 1994). It provided mechanisms to strengthen National Programs and for increased interaction among them and with IARCs. Comparative advantages in manpower and infrastructure among NARS were used to complement IARCs' efforts. Collaborative research projects were assigned to Lead NARS while less endowed NARS benefited from the ensuing technologies. The pool of well trained NARS maize scientists that was developed in the past 10-15 years interacted well with their colleagues in the IARCs for reciprocal influence on research agendas. The technologies that were developed during this period and in the immediate past are highlighted in the next section.

Highlights of Technology Options

The widespread adoption of improved open-pollinated varieties (OPVs) and subsequent increased production in the savanna of West Africa were made possible by the improved varieties based on the research conducted in the region within the past 30 years (IITA, 1992). As a result of the population improvement and streak resistance conversions carried out by the international centers (IITA and CIMMYT), in collaboration with the NARS, a wide range of resistant germplasm is now available for Africa's diverse environments. An array of breeding populations and varieties had been created (Table 2). They show distinct advantages in yield and other traits and are suited to the full range of environments in the predominantly lowland West Africa savannas. Improved germplasm is available that benefit farmers in many circumstances, ranging from the favorable to marginal. This represents an important contribution to the promotion of a sound agriculturally based economic development. In general, the region compares most favourably with the other regions of the world in the number of released modern varieties (Byerlee, 1994).

Since the mid 1980s, hybrid maize varieties adapted to the growing conditions of the African lowlands have been developed by IITA. They are available in both white and yellow grain types and with special traits that allow them to perform well under most of the major prevailing constraints (Table 2). For instance, the first available evidence of resistance/ tolerance in maize to *Striga* was made possible through the IITA hybrid research (Kim, 1994). Under high *Striga* infestation, hybrid 8322-13 produced 2.7t/ha compared to 0.0t/ha for the *Striga* susceptible hybrid, 8338-1; both hybrids gave comparable yields in *Striga*-free plots, i.e., 7.6 and 7.5t/ha for 8322-13 and 8338-1, respectively.

A sizable amount of evidence (from on-farm trials and village surveys) suggests that maize germplasm developed at IITA substantially increases yield under typical farm conditions across a wide range of management levels, in addition to their other advantages, such as, disease resistance (IITA, 1992). The general conclusion is that on farmers' fields, the improved varieties yield 30-100% more than the local varieties. Where the gap is closer to the lower end of this range, the local materials may actually be mixtures with, or of, improved varieties. Similarly, in Ghana, using CIMMYT germplasm-derived varieties, and in both marginal to relatively favoured land-extensive maize producing areas, the number of farmers who have adopted improved varieties is double the number who fertilized their maize (GGDP 1991). These observations, in part, reflect the fact that improved varieties often perform better than local varieties under low-input conditions (IITA, 1992; Byerlee, 1994).

Hybrid maize was perceived primarily as an option for more progressive farmers, mainly in the savanna, who are willing to invest in high quality seed. Results have shown that at very high rates of fertilizer application, the yield advantage of the presently available hybrids over improved OPVs is not sufficiently large to induce adoption (IITA, 1992). At moderate fertilizer rates (60-120 kg N/ha), the yield advantage of the hybrids is sufficiently large to make hybrid adoption worthwhile even after the removal of fertilizer subsidy.

Associated with the two dominant technology components (modern varieties and seed), increased plant density and line planting have also been adopted by farmers in the savanna, more than in the forest ecology, as long as these practices do not conflict with seasonal labor demands and intercropping systems. However, the general conclusion is that, increasingly, improved varieties and hybrids are available for most areas, but appropriate crop and resource management technologies, especially for maintaining soil fertility and increasing labor productivity, often are lacking (Byerlee, 1994).

The implication and challenges posed by this situation are examined in the following section.

Challenges for Improved and Sustained Production

One critical and often overlooked input for widespread adoption of maize varieties and hybrids by small-scale farmers is an effective system for supplying improved seed (Byerlee, 1994). Farmer-to-farmer seed distribution which disseminated improved varieties of rice and wheat throughout Asia, generally has been inadequate for maize, a cross-pollinated crop. The development of efficient seed industries is essential for providing more and a wider variety of improved maize seed to farmers at affordable prices.

The different types of maize seed available to farmers can be seen as a continuum from local varieties or landraces to improved OPVs, followed by non-conventional and conventional hybrids. These seed types differ from one another primarily in the technology used to produce them and in yield potential. Private sector companies that have emphasized hybrid seed, usually in Eastern and Southern Africa, generally have done a better job of providing seed at competitive prices, even to small-scale farmers, than countries emphasizing OPVs. On the other hand, in West and Central Africa where over 95% of the improved seed are OPVs, seed has been distributed to farmers through various development projects, especially in Nigeria, Ghana and Zaire. These are usually a one-time injection of new seed (Byerlee, 1994). No mechanism has been institutionalized to ensure that this seed will be replenished regularly so that farmers can maintain high level of productivity and to obtain newer varieties released by the research systems.

The question of who should participate in the seed industry has continued to occupy the attention of policy-makers in many countries. Each country must develop the appropriate combination of institutions to fit its stage of development, market size, type of farmers and maize growing environments. Although the IARCs are also public research organizations, the scope of their breeding research is international and they do not engage in commercial seed production.

Genuine concerns have been raised since the beginning of this decade as to the sustainability of the increased production and productivity of maize in the West African savannas (IITA, 1990). The question of sustaining intensification spotlights two distinct and critical issues, namely (i) economic sustainability, and (ii) environmental sustainability in keeping up soil fertility and keeping down pests and diseases. The foremost economic problem concerns fertilizer, a mainstay of intensification. The economics of using chemical fertilizer on maize in Africa is highly site-specific, depending on land pressure, agronomic variables, and fertilizer costs. With most countries committed to the removal of subsidy on agrochemicals, coupled with the effect of CFA devaluation and other elements of the structural adjustment program, high fertilizer prices may induce a reduction in maize hectarage and an increase in the areas planted to the more rustic traditional cereals, sorghum and millet. On-going maize improvement projects to reinforce maize with traits of edapho-climatic rusticity such as drought tolerance, increased nitrogen use efficiency, *Striga* resistance, etc. are most relevant.

Table 2. List of available and proven maize varieties and hybrids for the different lowland maize ecologies in West and Central Africa

Variety / Maturity Group	Grain type	Target ecology[a]	Major strong points	Major weak points
I.Full Season (120 days)				
(a)White open-pollinated				
. EV8443-SR, Ferke9143 Los Diamantes 8843	White dent	RF, DS, SGS	Strong roots, resistance to foliar diseases	Susceptible to *Striga*, downy mildew and storage insects
. EV8829-SR, Ferke9129-SR	White dent	RF, DS, SGS	Resistance to foliar diseases	Susceptible to *Striga*, downy mildew
. EV8722-SR, Acr 9022-SR	White semi-dent	RF, DS, SGS, NGS	Strong roots, clean ears/grains	- do -
. Mokwa 91 TZL Comp 3	White flint	RF, DS, SGS	Resistance to foliar diseases, clean ears/grains	- do - - do -
. TZL Comp 3x4 Co	White semi-dent	RF, DS, SGS	Strong roots, resistance to foliar diseases	Susceptible to *Striga*
. DMR-LSRW, Akure 93 DMR-LSRW, Acr 90 DMR-LSRW	White semi-dent	RF, DS, SGS, NGS	DMR, strong roots, resistance to foliar diseases, good husk cover	Susceptible to *Striga* and storage insect
. TZ9043-DMR-SR	White dent	RF, DS, SGS	DMR, strong roots, resistance to foliar diseases	Susceptible to downy mildew and *Striga*
. TZB-SR	White flint	DS, SGS, NGS	Resistance to foliar diseases, clean ears/grains	Susceptible to downy mildew and *Striga*
. TZPB-SR	White dent	RF, DS	Strong roots, resistance to foliar diseases	- do -
. TZSR-W-1, Funtua 88 TZSR-W-1, Ikenne 83 TZSR-W-1	White semi-dent	RF, DS, SGS	Resistance to foliar diseases, good husk cover	- do -
. TZB-SE	White floury	DS, SGS, NGS	Soft endosperm	Susceptible to downy mildew and *Striga*
. TZBR-Eldana 3 C2 IB.92 Eldana 3 C2	White semi-dent	RF, DS, NGS, SGS	Moderate resistance to borers (Eldana)	- do -
. NCRE Syn2	White semi-dent	DS, NGS, SGS	-	- do -
. Ndock 8701	White semi-dent	DS, NGS, SGS	-	Susceptible to downy mildew, *Striga*, and storage insects
. Okomasa	White dent	RF, DS, SGS	Strong roots, resistance to foliar diseases	- do -
. TZZ Comp 4 Co	White dent	RF, DS, SGS	- do -	

RF[a] = Rainforest, DS = Derived Savanna, SGS = Southern Guinea Savanna, NGS = Northern Guinea Savanna, SS = Sudan Savanna, CS = Coastal Savanna

Table 2 continued

Variety / Maturity Group	Grain type	Target ecology[11]	Major strong points	Major weak points
(b) White hybrids				
. 9021-18 STR (Single cross)	White semi-flint	RF, DS, SGS, NGS	Stable across ecologies, strong roots, clean ears/grains, moderate resistance to *Striga*	Susceptible to downy mildew
. 9053-18DMR (Top cross)	White semi-dent	RF, DS, SGS	DMR, strong roots,	-
. 8805-4(3-way cross)	White semi-dent	RF, DS, SGS, NGS	Drought tolerance	-
. 8766-12(3-way cross)	White semi-dent	RF, DS, SGS, NGS	-	-
. Cameroon Hybrid 1 (3-way cross)	White semi-dent	RF, DS, SGS, NGS	-	-
. Cameroon Hybrid 2 (Single cross)	White flint	DS, SGS, NGS	-	-
. 9022-13 STR	White flint	SGS, NGS	Moderate resistance to *Striga*	Susceptible to downy mildew
© Yellow open-pollinated				
. EV 8728-SR	Yellow semi-dent	RF, DS, SGS, NGS	Modest resistance to foliar diseases	Susceptible to downy mildew and *Striga*
. Suwan 1-SR Acr.91 Suwan 1-SR	Yellow flint	RF, DS, SGS, NGS	DMR, resistance to foliar diseases	Susceptible to *Striga*, mediocre husk cover
. Ikenne 88 TZSR-Y-1	Yellow semi-dent	RF, DS, SGS, NGS	Resistance to foliar diseases, good husk cover	Susceptible to downy mildew and *Striga*
. DMR-LSRY	Yellow semi-dent	RF, DS, SGS, NGS	DMR, resistance to foliar diseases, good husk cover	Susceptible to *Striga*
. TZB-SR SGY	Yellow semi-flint	DS, SGS, NGS	Resistance to foliar diseases	Light yellow grain, susceptible to downy mildew and *Striga*
(d) Yellow Hybrids				
. 8644-31(Single cross)	Yellow dent	RF, SGS, NGS	Modest DMR	Susceptible to *Striga*
. 8644-32(3-way cross)	Yellow semi-dent	RF, SGS, NGS	Modest DMR	Susceptible to *Striga*
. 8644-27(Single cross)	Yellow flint	RF, SGS, NGS	Modest DMR	-
. 8522-2(Single cross)	Yellow flint	RF, SGS, NGS	Modest DMR	-
. 8425-8(Single cross)	Yellow dent	SGS, NGS	-	Susceptible to *Striga* and downy mildew

Table 2 continued

Variety / Maturity Group	Grain type	Target ecology[1]	Major strong points	Major weak points
II. Intermediate(100-110 days)				
(a) White Open-pollinated				
. Acr.88 TZUT-SRW	White semi-dent	NGS	Strong roots, good husk cover	Susceptible to *Striga* and downy mildew
. EV 8744-SR	White dent	NGS	-	- do -
. Acr.9049-SR, Ikenne8149-SR	White dent	RF, NGS	Adaptation to inter-cropping, resistance to foliar diseases	- do -
. EV 8762-SR	White dent QPM	RF, SGS, NGS	Quality Protein Maize	- do -
. Obatanpa	White dent QPM	RF, SGS, NGS	Quality Protein Maize	- do -
(b) Yellow Open-pollinated				
. Suwan-2-SR	Yellow flint	RF, NGS	DMR, resistance to foliar diseases	Susceptible to *Striga*
. EV 8766-SR	Yellow flint QPM	RF, SGS, NGS	Quality Protein Maize	Susceptible to downy mildew and *Striga*
				Susceptible to downy mildew and *Striga*, poor husk cover
. Poza Rica 8326-SR		NGS	-	Susceptible to downy mildew and *Striga*
III. Early (85-95 days)				
(a) White Open-pollinated				
. Kamboinse 88 Pool 16 DT Farako-Ba 90 Pool 16 DT NAES 90 Pool 16 DT	Yellow flint	CS, NGS, SS	Drought tolerance, resistance to foliar diseases	Susceptible to *Striga*
. DMR-ESRW, Acr.89 DMR-ESRW	White dent	CS, RF, NGS	DMR, resistance to foliar diseases, good husk cover	- do -
				- do -
. EV 8730-SR	White semi-flint	CS, RF, NGS, SS	Resistance to foliar diseases	- do -
. TZESR-W	White flint	CS, RF, NGS, SS	Resistance to foliar diseases, good husk cover, clean ears/grains	- do -
. TZESR-W-SE	White flint	CS, RF, NGS, SS	Soft endosperm, resistance to foliar diseases	Susceptible to *Striga*
. TZE Comp 3x4	White soft endosperm	CS, RF, NGS	Resistance to foliar diseases	
. TZE Comp 3	White semi-flint	CS, RF, NGS	Resistance to foliar diseases	
. TZE Comp 4	White flint White dent	CS, RF, NGS	Resistance to foliar diseases	

Table 2 continued

Variety / Maturity Group	Grain type	Target ecology[11]	Major strong points	Major weak points
. Dorke-SR	White dent	CS, RF, NGS, SS	Resistance to foliar diseases	Susceptible to downy mildew and *Striga*
. AB 11	White dent	CS, RF, NGS, SS	Good husk cover	- do -
. BDP-SR	White flint	CS, RF, NGS, SS	Local variety type grains	Mediocre plant type, susceptible to downy mildew and *Striga*
. SYN E2	White dent	CS, RF, NGS, SS	-	Susceptible to downy mildew and *Striga*
(b) <u>Yellow open-pollinated</u>				
. DMR-ESRY	Yellow semi-flint	CS, RF, NGS, SS	DMR, resistance to foliar diseases, good husk cover	Susceptible to *Striga*
. EV 8731-SR	Yellow flint	CS, RF, NGS, SS	Resistance to foliar diseases	Susceptible to downy mildew and *Striga*
. Maka-SR	Yellow flint	SS	Modest tolerance to drought, modest high grain popping ability	Susceptible to foliar diseases, downy mildew and *Striga*
IV. Extra-early(80-85 days)				
(a) <u>White open-pollinated</u>				
. TZEE-W-SR	White semi-dent	SS	Modest resistance to foliar disease	Susceptible to downy mildew and *Striga*
. TZESR-WxGua 314 BC F6	White flint	SS	Resistance to foliar diseases	- do -
(b) <u>Yellow open-pollinated</u>				
. TZEE-Y-SR	Yellow flint	SS	Modest resistance to foliar diseases	- do -
. CSP-SR	Yellow flint	SS	Modest resistance to foliar diseases, bright yellow grain	- do -
. TZEF-Y	Yellow flint	SS	Modest resistance to foliar diseases	- do -

Environmental sustainability becomes a problem when cereals dominate the cropping regime as sorghum and maize do in the moist savanna. Cereals dominance leads to the so-called nutrient-mining and to the build-up of specific pests and diseases, including *Striga*. Tian *et al.* (1994) suggested several options for sustaining crop production on the low-activity-clay soils which are dominant in the moist savanna zone. IITA, in collaboration with NARS through the collaborative maize-based systems (COMBS) informal working group, is exploring ways to help promote sustainability by expanding the role of nitrogen-fixing legumes in the cropping system. For instance, herbaceous legumes can be used as relay or rotation crops in association with maize.

There is little doubt that scientists in the region have emphasized chemical fertilizer, as the major solution to the declining soil fertility, at the expense of research on alternative means of maintaining soil fertility from internal sources of nutrients (Byerlee, 1994). These internal sources generated on the farm include fallowing, legume rotations, green manure, alley cropping as well as farmyard manure (Tian *et al.*, 1994). The choice of which option to adopt will, of course, depend on many factors, including land and labour availability.

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The Role of WECAMAN in Maize Improvement and Technology Transfer in West and Central Africa

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Abstract

The West and Central Africa Maize Network (WECAMAN) with backstopping from IITA has during the past seven years established an effective collaborative research system with the active participation of NARS in West and Central Africa. The network has significantly improved the professional capacity and confidence of participating national programme scientists to carry out maize research to alleviate regional production constraints. New streak resistant, drought tolerant and high yielding maize varieties with a range of maturities, grain colour and texture, and improved agronomic practices (rates and time of fertilizer application, population, density, etc.) have been developed by the network and shared by the network member countries, resulting in the movement of maize into new frontiers. The network member countries have been assigned collaborative research projects on the basis of comparative advantage, cost effectiveness, and availability of human and infrastructural resources. These projects include breeding for intermediate, early and extra-early disease resistant varieties, Striga control, agronomic research on early and extra-early maturities, technology transfer, and on-farm level seed production. Research grants for collaborative research are allocated to member countries on competitive basis by an ad hoc Research Committee. In order to improve NARS scientific and research management capabilities, as well as their capability to transfer the available technologies, the network organizes training at all levels, biennial regional maize workshops, workshops on special topics, monitoring tours, and consultation visits by the network Coordinator and selected senior NARS scientists. To promote the adoption of the early and extra-early varieties, the network offers annually regional Uniform Variety Trials. In addition, the network is strengthening the research-extension-farmer linkages in member countries through financial support for the organization of annual national maize workshops. Furthermore, the network is providing/arranging technical and financial support to selected member countries for preparation of maize production guides for farmers and extensionists.

Résumé

Le Réseau de Recherche sur le Maïs en Afrique Occidentale et Centrale (WECAMAN) a durant les sept dernières années établi avec le soutien de l'IITA un système efficace de recherche collaborative auquel participent activement les SNRA d'Afrique Occidentale et Centrale. Ce réseau a considérablement amélioré les capacités professionnelles et la confiance des chercheurs nationaux dans le cadre de la recherche sur le maïs. Il a mené des activités tendant à atténuer les contraintes de production au plan régional. Grâce aux activités de recherche collaborative, les chercheurs nationaux ont amélioré leurs compétences de recherche et sont devenus une source pour la mise au

point de technologies. De nouvelles variétés de maïs de haut rendement, résistantes à la striure, tolérantes à la sécheresse et ayant des maturités, des couleurs de grain et des textures fort diversifiées ainsi que des pratiques agronomiques améliorées (doses d'engrais, dates d'application d'engrais, densité de population, etc.) ont été mises au point par le réseau et partagées par les pays membres du réseau. Il en est résulté une extension des superficies consacrées à la culture du maïs par le fait que le maïs a franchi de nouvelles frontières.

Les pays membres du réseau se sont vu confier des projets de recherche collaborative sur la base des avantages comparatifs, de la rentabilité et de la disponibilité de ressources humaines et infrastructurelles. Des subventions de recherche sont allouées aux pays membres sur une base compétitive par un comité ad hoc de recherche.

Les projets de recherche collaborative confiés aux pays membres comprennent la sélection de variétés intermédiaires, précoces et extra-précoces résistantes aux maladies, la lutte contre le *Striga*, la recherche agronomique sur les variétés précoces et extra-précoces, le transfert de technologies et la production de semences en milieu paysan.

Afin d'améliorer la capacité scientifique et la capacité d'administration de la recherche ainsi que la capacité de transfert des technologies disponibles, le réseau organise la formation à tous les niveaux : des ateliers régionaux biennaux, des ateliers traitant de thèmes spéciaux, des tournées d'inspection et des visites de consultation effectuées par le coordonnateur du réseau et certains chercheurs principaux des SNRA. Pour promouvoir l'adoption des variétés précoces et extra-précoces le réseau propose chaque année des essais régionaux de variétés uniformes. En outre, le réseau renforce les liens entre la recherche et la vulgarisation et les paysans dans les pays membres grâce à un soutien financier à l'organisation d'ateliers nationaux annuels sur le maïs. En outre, le réseau fournit ou aide à trouver un soutien technique et financier à certains pays pour élaborer des recommandations de production de maïs à l'intention des paysans et des vulgarisateurs.

Introduction

Maize (*Zea mays* L.) is an important staple crop in West and Central Africa. This is due largely to its genetic diversity, high yield potential, diverse uses (as human food, livestock feed, raw material for industry) and flexibility in fitting into the various cropping systems in the region. However, average maize yield in West and Central Africa is the lowest among the regions of the world. Among the major constraints to increased production and productivity of maize in West and Central Africa are erratic and low rainfall, declining soil fertility, diseases, pests, and poor management practices, particularly the use of unimproved and low yielding varieties. In order to alleviate these constraints, there is a need for national programmes to pool their resources together to develop and transfer technologies which would ensure sustained agricultural development and food self-sufficiency. The Semi-Arid Food Grain Research and Development (SAFGRAD) project was therefore created by African heads of states in 1977 under the auspices of the Organization of African Unity/Scientific and Technical and Research Commission (OAU/STRC). The Project, which was supported with mainly USAID funds sought to reinforce and coordinate agricultural research and develop suitable farming systems for improved productivity of sorghum, maize, millet, cowpea and groundnut. The International Institute of Tropical Agriculture (IITA) was assigned the responsibility for undertaking regionally oriented research and training activities for maize and cowpea. The International Crops Research Institute for Semi-Arid Tropics (ICRISAT) was responsible for the sorghum and millet components, while the Purdue University (USA) handled the farming systems component of the project. The project was under the umbrella of the OAU/STRC-SAFGRAD Coordination Office in Ouagadougou, Burkina Faso.

The phase I of the SAFGRAD project ended in 1986 with the development of adapted early maturing maize varieties and management practices for soil moisture conservation. Also, it was demonstrated during SAFGRAD I that regional commodity networks could help collaborating countries to develop and strengthen the capabilities of the national scientists and to share the technologies emanating from network efforts. The SAFGRAD Maize Network for West and Central Africa (WECAMAN) was, therefore, created as one of the four collaborative research networks of SAFGRAD phase II during an assembly of maize scientists from the sub-region in March, 1987. The objective of the SAFGRAD Maize Network was to assist national maize programmes in West and Central Africa to pool their human, infrastructural, material, and financial resources together in order to tackle production problems common to countries in the sub-region. The network comprised 17 member countries in West and Central Africa. A steering committee of national maize scientists had the responsibility for the research agenda and the implementation of the network activities, based on priority needs of member countries.

The second phase of the SAFGRAD Project terminated in March, 1993. As a result of the significant progress made by the SAFGRAD Maize Network, USAID approved funding for the continuation of the activities of the maize network during a two year period, October 1, 1993 to September 30, 1995.

The overall objective of WECAMAN at present is to increase farmers productivity, and income through the use of appropriate technologies identified or developed by the network and extended to farmers by extension services, other parastatal extension agencies, or non-governmental organizations (NGOs) in the respective member countries.

The network is currently focusing on the Guinea savanna zone of West and Central Africa where maize has the greatest potential and where returns to investments are greatest, due to adequate rainfall and sunshine and reduced levels of pest and disease attacks.

Due to fund limitations, the network now covers only eight countries in West and Central Africa where maize is an important staple crop. These include Nigeria, Cameroon, Benin, Togo, Ghana, Burkina Faso, Côte d'Ivoire and Mali. While membership of the steering committee is limited to countries that are regular members of the network, non-member NARS of the maize network are allowed to participate in workshops and regional maize trials organized by WECAMAN.

Generation and Transfer of Technology by WECAMAN

During the last decade, the generation and transfer of technology in West and Central Africa have been enhanced by the maize network through four main mechanisms, namely collaborative research projects, regional trials, exchange of scientific information and technologies, and human resources development.

Collaborative research projects

The first step in the establishment of the Maize Network for West and Central Africa was to prioritize the major constraints to maize production and productivity of the seventeen member countries of the network during an assembly of maize scientists from the sub-region in March, 1987. Also, the statuses of human resources, research infrastructure, and the capability of each country to generate technology were reviewed. This facilitated identification of problems of common interest and the strengths and weaknesses of each national programme. The network adopted the strategy of assigning technology development responsibilities to strong national programmes (Lead Centers) while all participating NARS were expected to adapt suitable technologies emanating from the network to their local conditions. The research responsibilities assigned to the Lead Centers were:

i) breeding varieties of different maturities for the semi-arid zone with emphasis on early and extra-early varieties: Burkina Faso, Cameroon, Côte d'Ivoire, Ghana and Togo;

ii) breeding for drought tolerance: Burkina Faso and Cameroon;

iii) breeding for streak resistance: Togo and Ghana;

iv) stemborer control: Côte d'Ivoire;

v) *Striga* control: Cameroon and Ghana; and

vi) agronomic research for maize varieties of different maturity groups: Cameroon and Nigeria.

Thus, each Lead Centre generated technologies which it shared with other network member countries, particularly the weaker (technology-adapting) NARS. The Network gave priority to screening and development of technologies that could alleviate the major maize production constraints. The progress made by the Lead Centers in the generation of technologies is summarized below:

Cameroon

***Development of early maturing varieties*:** Two early maturing synthetics were created through selection, line extraction, and crosses involving promising early and intérmediate germplasm.

***Development of drought tolerant maize*:** Drought tolerant synthetics were created from a drought resistant pool developed from Pool 16 DT and Drought Tolerant Synthetics obtained from SAFGRAD and IITA, respectively. Also, several other introductions were used to develop drought tolerant heterotic pools.

***Development of Striga resistant maize*:** Inbred lines developed from IITA *Striga* tolerant germplasm were evaluated in *Striga* infested soil. The promising lines were identified and used to develop a *Striga* resistant population. Two synthetic varieties, Syn D1 and Syn E2, have been developed and are being tested for tolerance of *Striga*.

***Seed treatment for improved plant establishment and yield*:** It has been established that seed treatment with Marshall 25 ST (carbosulfan) produced better emergence, improved seedling vigour, and 100% higher grain yield than untreated seed. Economic analysis showed a 1:33 cost/benefit ratio for the use of Marshall compared to the use of Thioral (current recommendation) for seed treatment. The advantage of Marshall 25 ST was due to its effect on soil insects, especially termites.

***Contribution of technology components to maize performance*:** The contribution of improved technological components to total maize yield in the Sudan savanna were as follows: 5% for tillage, 27% for seed treatment, 30% for varieties and 38% for fertilization.

***Management practices for early and extra-early maize*:** In order to maximize yields of early (DMR-ESRY and Pool 16 DT) and extra-early (TZEF-Y) varieties, N should be top-dressed 20-25 days after plant emergence as compared with the 30-35 days, recommended for medium and late maturing varieties. A combination of 80 x 20 cm spacing and 90-135 kg N/ha was essential for the full expression of the yield potential of the early and extra-early maize varieties.

Ghana

***Development of maize varieties of different maturities*:** Five breeding populations (120-day, 105-day, 95-day white dent, 120-day yellow flint/dent, and 95-day yellow flint populations) and two back-up gene pools (120-day and 105-day white dent) have been created. Also, the high yielding white dent maize, EV 8443-SR, has been converted to yellow grain colour through backcrossing, using Golden Crystal as the donor for the yellow colour.

***Improvement of streak resistance levels of elite varieties*:** The streak resistance level of three elite maize varieties developed in Ghana was improved through evaluation and selection, utilizing IITA streak resistance screening facilities during the 1-year visiting scientist tenure of Dr. Badu-Apraku at IITA. The varieties are:

i) Dorke (early, white variety extracted from Pool 16 SR),

ii) Abeleehi (intermediate, white variety extracted from Ikenne 8149 SR BC2 and Ikenne 8149 SR BC5), and

iii) GH 8363 SR (a high quality protein maize variety extracted from EV 8363-BC4).

These varieties have been released in Ghana and have been widely adopted by farmers.

Inbred line and hybrid development: Tropically adapted, disease resistant lines were developed and tested in hybrid combinations using elite inbreds from IITA. Hybrids GH 17 x 9071 and GH 5 x B73 outyielded Okomasa, the best Ghanaian open-pollinated variety by 31 and 30%, respectively. Both hybrids yielded as much, or higher than, IITA hybrid 8321-21. Work has been initiated on the formation of two heterotic pools for systematic hybrid development.

Inheritance of floury endosperm in local maize: The inheritance of the soft and floury endosperm of some local maize varieties from Ghana, Togo and Cameroon was studied using five generations derived from a cross between each local variety and a normal endosperm variety (F_1, F_2, and the reciprocal backcrosses). Results showed that Ghana and Togo locals possess an identical recessive gene for the floury endosperm. The Cameroon local, however, possesses a different single recessive gene for the floury endosperm.

Côte d'Ivoire

Local maize germplasm evaluation: One hundred and two maize accessions, collected from the central region of Côte d'Ivoire, were evaluated for twenty different characters. In addition to conserving these accessions, promising cultivars have been utilized in developing an early maturing maize population.

Stem borer control research: Three species of stem borers were identified in the central and northern parts of the country, namely, *Eldana saccharina, Sesamia calmistis*, and *Busseola fusca*. Using insecticide control, yield losses of up to 56.9% were attributed to stem borer damage on maize sown in June in the central-south part of Côte d'Ivoire.

Togo

Development of streak resistant maize: Streak screening facilities have been established at Ativeme near Lomé, Togo through the financial support of the network. Over 24,000 *Cicadulina* leaf hoppers can be raised per week to infest about 5,000 plants. Two maize populations, AB12 (Togo local floury x Pop 49-SR) and AB13 (Togo floury x Pop 43-SR) have been improved for streak resistance, good husk cover, soft endosperm, and prolificacy. ZL2-BD, another local-based maize population, has been improved for grain type and also crossed with Pool 16-SR for the generation of early maturing varieties. Three varieties, AB11, AB12, and AB13 with desirable local grain type and streak resistance have been developed for production in Togo.

Nigeria

Fertilizer requirement for maize/cowpea mixture: At Samaru, maize grain yield increased with increase in N application of up to 75 kg/ha. Maize responded significantly to P up to 40 kg P_2O_5 but there was no response to K. For cowpea, N application depressed grain yield significantly but there was a positive response to P at 80 kg P_2O_5/ha.

***Response of maize to zinc*:** Field trials conducted at five locations in the semi-arid zone of Nigeria during 1988-90 showed that maize grain and dry matter yields increased with increasing zinc (1-2 kg Zn/ha) application across locations. The optimum Zn fertilizer rates for the soils studied ranged between 1 and 2 kg Zn/ha.

***Field evaluation of Nigerian made granular urea*:** There were no significant differences among the sources of N in all the five semi-arid locations studied. Generally, the Nigerian made urea gave higher grain and straw dry matter yields than imported prilled urea but slightly lower yields than CAN at all locations. The optimum N requirements for maize in all the locations were between 100 and 150 kg/ha. At rates higher than 100 kg/ha, all the three N fertilizer sources had varying acidifying effects on the soil; the order of magnitude being CAN < granular urea < prilled urea.

Burkina Faso

One effective way of escaping the havoc caused by drought is the use of early and extra-early varieties. These types of maize are appropriate for the Sudan savanna zone since they mature within 2.5-3 months. Before the inception of the SAFGRAD project in 1969, there was no international center working on extra-early maize varieties. The establishment of the SAFGRAD project allowed IITA to move to the Sudan savanna zone and to initiate the development of improved early and extra-early varieties for Sudan savanna zone. The work continued up to the end of SAFGRAD phase 2 and was jointly executed by IITA resident scientists and the national programme of Burkina Faso. The activities included:

***Development of drought tolerant maize varieties*:** Pool 16 DT has been taken through four cycles of full-sib recurrent selection with emphasis on drought tolerance, using two levels of soil-moisture stresses created by planting in tied or simple (open) ridging systems. Four sets of experimental varieties have been developed from the 1986, 1988, 1990 and 1992 full-sib progeny yield trials. The population and the experimental varieties have been improved for streak resistance under controlled leaf hopper infestation. Varieties extracted from Pool 16 DT have performed very well in the regional uniform variety trials and have been released by several national programmes and/or utilized in several breeding programmes.

***Development of extra-early maize varieties*:** Several extra-early maturing maize varieties (less than 82 days to maturity) have been developed from crosses involving local and improved germplasm. Emphasis has been on the improvement of plant type and grain yield, while retaining earliness and disease resistance. Improvement for resistance to foliar fungal diseases (Helminthosporium leaf blight and Curvularia leaf spot) have also been carried out. The varieties (TZEE-W, TZEE-Y and CSP-early) have been converted for streak resistance and made available to national programmes through the regional trials. TZEF-Y is currently undergoing conversion for streak resistance.

***Incorporation of streak resistance into some elite early varieties*:** Two promising early maturing local varieties (Blanc Deux Précoce (BDP) from Benin and Maka, from Mauritania) have been converted for streak resistance. Also two breeding populations, DT yellow Pool and DT white Pool, created from the best materials in the programme are being converted for resistance to streak and are at the BC_2F_2 stage.

The results of the SAFGRAD impact assessment study conducted in 1992/93 revealed that the NARS of the maize network were seriously engaged in technology generation, and there was much more work in development than in adaptation in some countries. For example, Cameroon, Ghana and Nigeria were identified as the most active in the development of new maize technologies, with about ten times more technology generation than adaptation. The report further indicated that there had been marked increases in the number of activities undertaken and completed by NARS scientists. Both the numbers and types of experiments carried out on-station and on-farm had more than doubled. It was concluded that the activities of the maize network had definitely contributed to this change (Sanders *et al.*, 1994).

Several innovations have been introduced into the network to make it more effective in the generation and transfer of technology since 1994 under the new structure and funding. Member countries have been assigned collaborative research responsibilities on competitive basis. The idea of competitive research grants has been introduced for all collaborative project support so as to motivate NARS scientists to increase research output and to be creative. An ad hoc Research Committee composed of three agricultural experts from non-member countries has been appointed by the Steering Committee. The ad hoc Research Committee reviews research proposals submitted by the network member countries, selects lead NARS and allocates research funds on competitive basis. The criteria established by the Steering Committee for assigning research responsibilities include the submission of well conceived project proposal, qualified research personnel, and financial and infrastructural resources.

The ad hoc Research Committee met in Bouake in April, 1994, reviewed the 37 collaborative research proposals submitted by member countries, assigned research responsibilities and allocated an amount of $80,700 for 1994 cropping season. The ad hoc Research Committee has reviewed the progress reports on the 1994 collaborative research projects and has allocated an amount of $105,000 to member countries for the 1995 cropping season. Thus, WECAMAN has become an important source of research funds for technology generation and transfer. The list of collaborative research projects assigned to the eight network member countries is presented in Table 1 which shows that research responsibilities cover all the major researchable constraints to increased maize production and productivity.

Enough information on time of planting, spatial arrangement, fertilizer rates and population densities are now available to national programmes in the sub-region. The maize network is therefore focusing research on soil fertility problems and the maintenance of soil fertility through the use of cover crops, alley cropping, etc. There is increased emphasis on technology transfer through on-farm verification trials, demonstrations, and community level seed production.

At present, the Network Coordinator spends about 40% of his time on breeding for early and extra-early varieties with resistance/tolerance to drought, *Striga,* and streak virus; seed multiplication of maize varieties nominated for regional trials; establishment of nurseries for training purposes; and germplasm conservation and maintenance. Several promising early and extra-early varieties have been developed and are currently being tested.

The SAFGRAD impact assessment team identified technology transfer as one of the major constraints to the adoption of technologies generated by the network. In an attempt to alleviate this constraint, the network is presently taking a number of measures. These include the strengthening of research-extension-farmer linkage in member countries, organization of workshop on technology transfer, and financial support for collaborative projects on technology transfer.

Table 1. Collaborative research projects assigned to network member countries in 1994.

Project title	Countries with assigned responsability
Breeding for disease resistant intermediate maturing maize varieties	Cameroon, Ghana, Côte d'Ivoire
Breeding for drought tolerant and disease resistant early maturing varieties	Burkina Faso, Ghana
Breeding for disease resistant extra-early maturing maize varieties	Burkina Faso, Cameroon
Striga control	Cameroon, Ghana, Benin, Mali and Togo.
Agronomic research for intermediate early and extra-early maize varieties	Burkina Faso, Cameroon, Côte d'Ivoire, Mali, Nigeria and Benin
Promotion of technology transfer	Nigeria, Mali, Togo, Côte d'Ivoire, and Benin
Promotion of on-farm level seed production	Burkina Faso, Cameroon, Togo, Mali and Benin.

The network is encouraging and assisting member countries to organize annual maize workshop/research planning and to publish hand books on maize for extensionists and farmers, in an effort to strengthen researcher-extentionist-farmer linkages within the respective countries. The annual workshop/research planning involves researchers, extentionists, policy makers and farmers and provides the fora for reviewing research findings, grower recommendations, and agricultural policies.

The adoption of improved early and extra-early varieties being promoted by the network depends on the availability of seeds of the varieties in quantity and quality. Stimulating the network member countries to develop efficient on-farm level seed production schemes is, therefore, an important component of the network's technology transfer activity. The network is funding community level seed production schemes in Burkina Faso, Benin, Cameroon, and Togo. Also, a seed production course, with emphasis on community seed production, was planned for August, 1995 in Ghana for network member countries.

Exchange of scientific information and technologies

In order to increase the chances for increased interaction and follow-up activities, visits are undertaken annually by the network coordinator and selected senior NARS scientists to several national programmes. In addition, experienced steering committee members are assigned to visit needy member countries. The visits were essentially designed to ensure that all member NARS participate effectively in network activities.

Monitoring tours are organized biennially by the network to enable national programme scientists from all member countries to visit national maize programmes in two or three countries, to interact with each other, and to discuss production constraints, research methodologies, appropriate technologies and linkage of research with development agencies.

Monitoring tours were organized in 1988, 1990 and 1994 for a total of 21 scientists. Scientists from two different sets in seven countries visited Burkina Faso and Ghana in 1988, and Cameroon and Nigeria in 1990. The 1994 monitoring tour, involving seven scientists from member countries, visited Mali and Côte d'Ivoire.

Regional trials

The maize network has been a major mover of technologies developed by various sources. To enhance the exchange of germplasm, varieties, and other improved technologies among national programmes, the maize network organizes annually three types of regional uniform variety trials (RUVTS), namely, RUVT-early, RUVT-extra-early, and regional adaptive trials. The trials are offered to both member and non-member countries of the network. Also, the trials have promoted the exchange of improved germplasm and other technologies within the sub-region, and allowed the evaluation of regional variation in maize diseases and insect pests (Table 2). Entries have been nominated by various national programmes, CIMMYT, and IITA. The improved technologies available to farmers have resulted in the extension of maize hectarage in all maize network member countries (Table 3). For example, in Cameroon, the total maize production has doubled in 10 years; over 60% of this increase is attributable to increase in maize area in the savanna which is planted almost exclusively to improved varieties. The streak resistant variety, TZB/TZB-SR, is estimated to cover 15% of the maize area of 75.000 ha. In the semi-arid region of Cameroon, where sorghum and millet are the predominant crops, the introduction of improved early maize varieties has resulted in the doubling of maize area to 35,000 ha. Also, the results of the SAFGRAD economic impact study revealed that maize production in Ghana has approximately quadrupled within a decade (1982-1991). The area under improved varieties increased from 20% to 50%. The internal rate of return to the public investment in the national maize programme was reported to be 74% (Sanders *et al.*, 1994).

Table 2. Maize varieties made available to NARS through the regional trials organized by WECAMAN.

Variety	Origin
Late and intermediate maturing varieties (110-120 days) for northern Guinea savanna zone.	
Abelechi	Ghana
Aburotia	Ghana
AB 22	Togo
CSM 8710	Cameroon
Okomasa	Ghana
Dobidi	Ghana
EV8422-SA	CIMMYT-IITA
EV8428-SR	CIMMYT-IITA
EV8435-SR	CIMMYT-IITA
EV8443-SR	CIMMYT-IITA
EV8444-SR	CIMMYT-IITA
EV8449-SR	CIMMYT-IITA
FARAKO-BA 85 TZSR-W-1	IITA
FARAKO-BA 85 TZSR-Y-1	IITA
NDOCK 8701	Cameroon
LOUMBILA 84 TZUT-Y	IITA & Burkina Faso
TZB-SR	IITA
TZPB-SR	IITA
Golden Crystal	Ghana
Composite 4	Ghana
Zm10	Senegal
Synthetic C	Senegal
BDS	IRAT/Senegal
AB22	Togo
CJ1	IRAT/Benin
Staha	Tanzania
IRAT 100	IRAT/Burkina Faso
IRAT 102	IRAT/Burkina Faso
IRAT 178	IRAT/Côte d'Ivoire
NH2	IRAT/Benin
Elite x Early	Ghana
Mexican Composite	
Early maturing (90-100 days) and/or drought tolerant varieties for Sudan savanna.	
Across 86 Pool 16 DT	IITA-SAFGRAD
Across 87 Pool 16 SR	IITA
Across 88 Pool 16 DT	IITA-SAFGRAD
BDP-SR BC5	Benin/SAFGRAD
DMR-ESRW	IITA
DMR-ESRY	IITA-SAFGRAD
DR Comp. Early	IITA-SAFGRAD
EV 8730-SR	CIMMYT-IITA
EV 8731-SR	CIMMYT-IITA

Farako-Bâ 86 Pool 16 DT	IITA-SAFGRAD
Farako-Bâ 88 Pool 16 DT	IITA-SAFGRAD
FBC 6	Burkina Faso
Ikenne 88 BU-ESRW	IITA
Kamboinse 88 Pool 16 DT	IITA-SAFGRAD
Maka-SR BC5	Mauritania-SAFGRAD
SAFITA-2	IITA-SAFGRAD
TZE Comp. 3 x 4	IITA
TZESR-W	IITA
TZESRW-SE	IITA
Dorke SR	Ghana
Mexican 17 Early	Ghana
Jaune dente de Bambey	Senegal
MTS	IRAT/Côte d'Ivoire
Across 90 Pool 16 DT	IITA/SAFGRAD
Extra-early maturing varieties for Sudan savanna and to bridge hunger gap in other zones.	
(Across 8131 x JFS) x Local Raytiri	IITA-SAFGRAD
CSP	IITA-SAFGRAD
CSP-SR BC5	IITA-SAFGRAD
CSP x Local Raytiri	IITA-SAFGRAD
Pool 27 x Gua 314	IITA-SAFGRAD
Pool 28 x Gua 314	IITA-SAFGRAD
Pool 30 x Gua 314	IITA-SAFGRAD
TZEE-W1	IITA-SAFGRAD
TZEE-W2	IITA-SAFGRAD
TZEE-White Pool	IITA-SAFGRAD
TZEE-W SR BC5	IITA-SAFGRAD
TZEE-Y	IITA-SAFGRAD
TZEE-Yellow Pool	IITA-SAFGRAD
TZEE-Y SR BC5	IITA-SAFGRAD
TZEE-Y	IITA-SAFGRAD
TZESR-W x Gua 314	IITA-SAFGRAD

Table 3. Maize production trends in some selected countries of West and Central Africa.

	Production area (ha)		Grain production (tons)		% of total area under improved varieties in 1988
	1986	1989	1986	1989	
Benin	442,785	478,995	352,849	424,042	41
Burkina Faso	165,000	206,000	155,000	171,000	27
Cameroon	-	500,000	-	600,000	18
Chad	32,419	45,292	25,293	41,000	-
Côte d'Ivoire	468,000	600,000	361,000	450,000	10
Ghana	472,000	567,000	560,000	750,000	43
Mali	-	126,000	-	228,000	36
Mauritania	2,624	11,303	1,150	3,104*	-
Niger	2,194	3,047	4,735	4,776	-
Nigeria	-	3,5 m	-	4,4 m	40-50
Senegal	95,000	105,000	100,000	133,000*	100
Togo	-	258,000	-	245,000	15

* 1990 Figures ** Production under irrigation

Source: 1989-1990 CIMMYT World Maize Facts and Trends.

Human resources development

Lack of sufficient, well trained and skilled national programme scientists and technicians constitutes one of the major constraints to the generation and transfer of technology in the sub-region. To overcome this constraint, the maize network has organized training programmes at all levels since 1988. Among these is a 5-month residential course which has trained a total of 23 technicians between 1988 and 1994 during the growing season. The course emphasized field plot techniques, trial management, variety maintenance, seed multiplication, statistical analysis, data interpretation and report writing.

The maize network has also organized many workshops, seminars and in-service courses to strengthen the research capabilities of NARS and to promote an exchange of information and a spirit of friendship and common purpose among national programme scientists. Thus, a major accomplishment of the network is the breaking down of linguistic barriers among NARS scientists.

Three biennial joint workshops and a special purpose seminar have been organized jointly for the maize and cowpea scientists in West and Central Africa since 1987. During the biennial workshops, scientific papers were presented while the overall activities and progress of the networks were reviewed and necessary changes in focus and direction made. A special purpose seminar for research agronomists was organized jointly by the SAFGRAD maize, cowpea, and sorghum networks from 7 to 19 January, 1991 at IITA, Ibadan, Nigeria. Also a special workshop on *Striga* control and technology transfer was organized for eight scientists from each of the network member countries in Ibadan (Nigeria) and Cotonou (Benin) from October 3-14, 1994.

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Towards Developing cultivars of maize for the transitional and savanna zones of Côte d'Ivoire (Progress Research note)

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Abstract

In 1993 and 1994, CIMMYT open pollinated streak resistant maize varieties (intermediate and late) and CIMMYT white and yellow late hybrids (in 1994 only) were evaluated at Bouaké in the transitional forest/savanna zone and Sinématiali in the Guinea savanna Zone. Under normal growing conditions in both zones, open pollinated varieties and hybrids of 2 maturity groups (late and intermediate) yielded higher in the savanna than in the transitional zone. The yield reduction was higher for the hybrids compared to the Open Pollinated Varieties (OPVs) with white hybrids performing better than yellow hybrids. The best CIMMYT white hybrid out yielded the local regional commercial hybrid by 35%. In almost all cases, the period from planting to 50% silking was longer in the savanna than in the transitional zone, and the percentage of root lodging was much higher in the savanna than in the transitional zone, because of high termite damage in that ecology. However the stem lodging was higher in the transitional zone than in the savanna zone, due to the higher prevalence of stem borers and/or stalk rot in the transitional zone. In the savanna the yield advantage of white hybrids over OPVs was evident, but not in the transitional zone.

Résumé

En 1993 et 1994, les variétés CIMMYT (intermédiaires et tardives) de maïs à pollinisation libre résistant à la striure et les hybrides CIMMYT tardifs jaunes et blancs (en 1994 seulement) ont été évalués à Bouaké (zone de transition forêt/savane) et à Ferkessedougou (zone de savane guinéenne). Lorsque les conditions climatiques ont été normales dans les deux zones, tous les génotypes de maïs (variétés à pollinisation libre, hybrides de tout groupe de maturité (tardifs et intermédiaires) ont produit plus dans la savane que dans la zone de transition. La réduction de rendement était plus marquée pour les hybrides comparativement aux variétés à pollinisation libre. La performance des hybrides blancs étaient meilleure à celle des hybrides jaunes. Le meilleur hybride blanc du CIMMYT a surpassé en rendement de 35% l'hybride local commercialisé dans la région, ce qui fait ressortir l'efficacité de la méthode utilisée par le CIMMYT au Mexique pour mettre au point des hybrides destinés à l'écologie tropicale des basses terres. Dans tous les cas, la période du semis à 50% de formation de soie était plus longue dans la savane que dans la zone de transition et le pourcentage de verse des racines était plus élevé dans la savane que dans la zone de transition, ce qui traduit la présence de termites dans cette écologie. Par contre, la verse des tiges était plus grande dans la zone de transition que dans la savane, révélant ainsi la plus grande prévalence

des borers des tiges et/ou de la pourriture des tiges dans la zone de transition. La mécanisation de la récolte du maïs serait difficile dans les deux écologies à moins d'éliminer les termites et les borers des tiges, ou de mettre au point et d'utiliser des variétés résistantes. Dans la savane, l'avantage de rendement des hybrides blancs par rapport aux variétés à pollinisation libre était évident mais tel n'était pas le cas dans la zone de transition.

Background Information

Côte d'Ivoire is characterized by two climatic zones.
(i) Zone with two rainy seasons (South, Central, East, and North-east). The annual rainfall is high in the South (Gagnoa: 1456mm), and moderate in the transitional forest/savanna zone (Bouaké: 1193 mm) and North-east. In the first season , March to June, rains are abundant and often irregular in the transitional zone, where there is very frequently a short season with low rainfall in May. In the second season, rains are less regular in the South (September to November), and are brief (2 months) and regular in the transitional zone (end of August to end of October).
In this zone, maize is cultivated during the first rainy season, using early maturing varieties. In the transitional zone, however, the irregularity of rains in May (flowering stage) and the low temperature associated with high humidity in July pose problems for satisfactory growth and maturity of maize. Maize can be grown in the transitional zone as a monocrop, if late maturing varieties are planted in June (March and 1976).

(ii) The second zone is found in the West and North. It is characterized by a single rainy season with high rainfall in the North (Ferkéssedougou: 1350 mm) from April to October, and very abundant in the West (Man : 1736 mm) from March to October. There are two low rainfall periods in May and July-August. In the West, two crops of maize are usually planted: an early variety followed by a second crop after harvesting; for the second crop, late varieties can be cultivated as a monocrop. However, the high rainfall renders makes the harvesting of the first crop difficult and can cause water logging in the soils under monocropping. In the North, a monocrop (late varieties) planted in June has a very good chance of success, in spite the of the risk of water logging in August. (Marchand 1976).

Temperature is generally high (26°-27° monthly average) during the planting season in all zones, whereas the annual daylight duration increases from the South to the North (1788h at Gagnoa, 2064h at Bouaké, and 2780 h at Ferkéssedougou. (Marchand 1976).

After rice, maize is the second most important cereal consumed in Côte d'Ivoire (Attiey Koffi. personal communication). About 689000 ha of maize was planted Côte d'Ivoire (189-1991) with 491000 tons produced at 0.7t/ha national yield average.(CIMMYT.1992). Maize is grown all over the country, but about 85% of the maize area is located in the North (Savanna) with 47%, and in the transitional zone with 38% (Marchand 1976).

The objective of this paper is (I) to present the yield performance of maize genotype of different genetic background (hybrids and Open Pollinated Varieties) and maturity (late and intermediate streak resistant varieties) in the two ecological maize zones of Côte d'Ivoire; (ii) to inform policy makers, farmers, extension services, NGOs and other agricultural development agencies operating in Côte d'Ivoire about the existence of new streak resistant varieties and hybrids suitable for the transitional and savanna zones of Côte d'Ivoire.

Materials and Methods

Bouaké and M'Be were used as the representative sites of the transitional zone in 1993 and 1994 respectively, whereas, Sinématiali was used as the representative site for the Guinea savanna in 1993 and 1994. Sinématiali is situated 18 km north of Ferkéssedougou, and the long period rainfall average was assumed to be similar to that of Ferkéssedougou.

In 1993, 18 intermediate white, and 36 late white and yellow streak resistant varieties were evaluated at Bouaké (transitional zone) and Sinématiali (guinea savanna zone). In addition to the group of open pollinated varieties, two groups (white and yellow) of 18 CIMMYT hybrids each, were evaluated in 1994 at the same locations. In 1993, trials were planted on July 2 at Bouaké, and on July 14 at Sinématiali. The 1994 trials were planted at Bouaké on July 12, and at Sinématiali on July 15. Those periods correspond to the recommended period for planting in both ecological zones. A lattice design (6 X 6) with 4 replications was used for the group of late materials and randomized complete block design with 4 replications was used for the group of intermediate varieties and hybrids.

For the open pollinated varieties, each plot included four rows 5 m long, with 0.75 m between rows and 0.50 m between plants.

Rows were over planted and thinned to approximately 53000 plants ha^{-1}. The two central rows were used for data collection. For the group of hybrids, each plot included two rows 5 m long, with 0.75 m between rows and 0.50 m between plants for a population density of 53000 plants ha^{-1}. In this case, the two rows were used for data collection. Fertilizer (106 N- 60 P2O5- 60 K2O) was applied at the two sites according to the recommended timing. This fertilizer rate is higher than the recommended rate for farmers. For the weed control, a preemergence herbicide (Primagram) was applied at planting but hand weeding done throughout the growing season. In the transitional zone, Furadan 5G was applied to control stem borers.

Days from planting to silking were obtained from the date at which 50% of the plants/plot had silks. Data on root and stalk lodging were recorded just before harvest. For root lodging, the number of plants that are leaning 30° or more from the perpendicular at the base of the plant where the root zone starts were recorded and the percentage was calculated (CIMMYT. 1995). For stem lodging, number of plants with stalk broken below the ears but not above the ears was recorded and percentage calculated. Grain yield expressed in Mg ha^{-1} at 15% moisture was obtained by assuming a shelling percentage of 80%. Analyses of variance (ANOVA) were conducted with AGROBASE4.

Results and Discussions

In 1993, the rainfall was lower than normal in both Bouaké and Sinématiali with much

higher deficit at Sinématiali. Rainfall in 1994 was below the average in the two locations, but none of the sites could be considered as dry.
Mean yields for the late Open Pollinated Varieties (OPVs) varied from 4.4 to 7.2 tons ha^{-1} at Bouaké and from 4.2 to 6.7 tons ha^{-1} at Sinématiali. This small difference in yield in favor of Bouaké (transitional zone) might be due to the difference in rainfall. Varieties developed from La Posta Population gave the highest yield at both locations. The year 1993 was normal at Bouaké, but dry at Sinématiali. For the same year, mean yields for the intermediate OPVs ranged from 2.9 to 5.1 tons ha^{-1} at Bouaké and from 4.2 to 6.5 tons ha^{-1} at Sinématiali, indicating the highest potential of the guinea savanna ecology compared to the transitional zone when varieties of the right maturity group are grown. Similar results were reported by IITA for the transitional and savanna zones of Nigeria (IITA. 1990). Among the intermediate maturing varieties TZUT-W-SR from IITA gave the highest yield at Sinématiali, whereas EV8749SR (CIMMYT variety) out yielded all varieties at Bouaké.

The results for 1994 showed that yield averages for the late OPVs varied from 4.4 to 7.2 tons ha^{-1} at Bouaké and from 6.5 to 8.3 at Sinématiali, whereas mean yields for the intermediate OPVs ranged from 4.5 to 6.2 tons ha^{-1} at Bouaké and from 5.7 to 8.0 tons ha^{-1} at Sinématiali. Among the late OPVS, varieties from La Posta again gave the highest yield at Bouaké and Sinématiali. In the intermediate group, the highest yielder was also a variety from La posta, made of early streak resistant lines. These data reflect the broad adaptation of La posta. This maize population was already suggested for release in Côte d'Ivoire (Marchand 1976).

In summary, the mean yield of the late OPVs in the savanna in 1994 was 7.5 tons ha^{-1} compared to 6.0 for the transitional zone and the average yield of the intermediate OPVs was 7.3 tons ha^{-1} in the savanna and 5.3 in the transitional zone. For the hybrids the same trend is observed, i.e the yield was higher in the savanna zone than in the transitional zone. For the white hybrids, mean yields varied from 5.0 to 7.3 tons ha^{-1} at Bouaké and from 7.2 to 9.7 tons ha^{-1} at Sinématiali. For the yellow hybrids, the average yields ranged from 5.3 to 6.7 tons ha^{-1} at Bouaké and from 6.4 to 8.3 tons ha^{-1} at Sinématiali. These figures reflect the better yield performance of CIMMYT white hybrids compared to yellow hybrids and the highest yield potential of the savanna compared to the transitional zone of Côte d'Ivoire.

The best CIMMYT white hybrid (9.7 tons ha^{-1}) out yielded the local commercial hybrid (Oba Super 1, 5.9 tons ha^{-1}) by 35%, indicating that some hybrids developed in Mexico can be grown successfully in the transitional and savanna zones of Côte d'Ivoire. Furthermore the hybrid method development used by CIMMYT in Mexico is efficient for the lowland ecology of Côte d'Ivoire. In the savanna, the best hybrid yielded 9.7 tons ha^{-1}, and the best OPV (Sinématiali 9043) yielded 8.3 tons ha^{-1}, whereas, in the transitional zone the yield of the best hybrid (7.5 tons ha^{-1}) was similar to the yield of the best OPV S9343SRF2 (7.2 tons ha^{-1}), indicating that it would be more profitable to use OPVs in the transitional zone. In almost all cases, the period from planting to 50% silking was longer in the savanna than in the transitional zone, and the percentage of root lodging was much higher in the savanna than in the transitional zone reflecting the presence of termites in that ecology. Stem lodging was higher in the transitional zone than in the savanna, reflecting the higher prevalence of stalk borers and/or stalk rot in the transitional zone. The mechanization of maize harvest operation would be difficult in both ecologies unless termites and stem borers are controlled, or resistant varieties are developed and used. In the savanna the yield advantage of white hybrids over OPVs was evident, but not in the transitional zone.

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Amélioration de la Productivité des Systèmes Culturaux à Base de Mil

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Résumé

Le mil est la principale céréale cultivée au Sénégal. On le rencontre dans tout le pays mais le bassin arachidier constitue la principale zone milicole. Il est principalement cultivé selon deux systèmes : culture pure et culture associée. Les rendements demeurent faibles en milieu paysan, et ne dépassent pas 750 kg/ha à cause de plusieurs facteurs dont essentiellement la faiblesse de la pluviométrie, la dégradation des sols, la non-disponibilité de semences de variétés améliorées et le manque d'appui institutionnel et organisationnel.

Des travaux de vérification et transfert de technologie ont été menés de 1990 à 1994 avec le concours du SAFGRAD pour l'amélioration de la production. Il ressort des résultats que: dans le Centre-Sud, le Souna 3 a produit 28 % de plus que les variétés locales. Par ailleurs, les enquêtes menées après quatre années d'expérimentation ont montré une bonne diffusion des variétés améliorées. La fumure organique (2 t/ha) associée à la moitié de la dose de fumure minérale préconisée donne des rendements légèrement inférieurs de 14 % à ceux obtenus avec la dose de fumure minérale vulgarisée. Les mêmes rendements étaient obtenus avec 2 t/ha de fumier plus 30 kg/ha de P_2O_5.

Le semis simultané du mil et du niébé était plus adapté pour la culture associée. Les meilleures variétés de mil pour l'association sont le Souna 3 et IBV 8004 respectivement pour le Centre-Sud et le Centre-Nord, tandis que pour le niébé, Ndiambour a eu le meilleur comportement.

Le meilleur écartement de semis a été une double ligne de niébé entre les lignes de mil semées aux écartements 150 cm x 60 cm. Cela donnait un coefficient d'équivalence en surface de 1,17 et 1,27 respectivement à Nioro (Centre-Sud) et Bambey (Centre-Nord). Un rendement en grains équivalent à 80 % de celui de la culture pure a été obtenu avec cette géométrie de semis. La technique de compostage a été vulgarisée auprès des paysans et des agents techniques.

La collaboration avec les ONG (Organisations Non Gouvernementales) et le Programme National de Vulgarisation Agricole a permis de voir l'intérêt de renforcer les moyens d'application des résultats en fournissant un appui aux paysans.

Abstract

Millet is the major cereal grown in Senegal. It is cultivated in the whole country but the peanut basin is the main millet growing area. There are essentially two cropping systems: sole cropping and intercropping. Yields remain low at farmers level and do not exceed 750 kg/ha because of several factors including essentially low rainfall, soil degradation, lack of improved seeds varieties and of institutional and organizational support. Technology verification and transfer work was conducted from 1990 to 1994 with SAFGRAD assistance for production improvement. Results showed that:

- In Central-South, Souna-3 produced 28% more than local varieties. Furthermore, surveys undertaken after four years of testing revealed a good dissemination of improved varieties. organic manure (2t/ha) combined with half the recommended rate of mineral fertilizer gives yields slightly inferior by 14% to those obtained with the released mineral fertilizer application.. The same yields were obtained with 2 t/ha of manure plus 30 kg/ha of P205. simultaneous planting of millet and cowpea was more adapted for intercropping. The best millet varieties for intercropping are respectively Souna-3 and IBV8004 for Central-South and Central-North while the cowpea variety Ndiambour was the best performing.

The best planting spacing was a double row of cowpea between millet rows planted with spacings of 150 cm x 60 cm. This resulted in a land equivalent ratio of 1.17 and 1.27 respectively in Nioro (Central South) and Bambey (Central North). A grain yield equivalent to 80% of that of sole crop was obtained with such a planting spacing. The composting technique was released among farmers and technical staff.

The collaboration with NGOs and the National Agricultural Extension Programme revealed the need for strengthening the means of applying research results by supporting farmers.

Introduction

Le mil est la principale céréale cultivée au Sénégal. On le rencontre dans tout le pays mais le bassin arachidier constitue la principale zone milicole. Il est cultivé sous forme de culture pure continue dans les champs de case autour des habitations ou en rotation avec une légumineuse (arachide et niébé) ou d'autres céréales (maïs, sorgho) dans les champs de brousse. Les associations culturales mil/niébé, mil/sorgho et mil/arachide sont couramment rencontrées au Centre Nord et au Sud.

Les rendements demeurent faibles en milieu paysan et ne dépassent pas 750 kg/ha (Fofana et Mbaye, 1990) à cause de plusieurs facteurs dont essentiellement:

- la faiblesse de la pluviométrie;
- la dégradation des sols;
- la non-disponibilité de semences des variétés vulgarisées;
- le manque d'appui institutionnel et organisationnel.

Des travaux de vérification et transfert de technologie ont été menées de 1990 à 1994 en station et milieu paysan sur cinq activités :

- les essais de démonstrations de production de mil;

- la valorisation de la matière organique et du phosphate naturel;
- l'association culture mil/niébé;
- la formation des agents techniques et des paysans aux techniques de compostage;
- les enquêtes spécifiques sur les pratiques culturales du mil.

Les objectifs principaux du projet étaient de:

a) promouvoir l'utilisation des résultats de recherche par les paysans;
b) fournir aux paysans plusieurs options technologiques susceptibles d'accroître sensiblement la production et la productivité;
c) vérifier la durabilité agronomique et économique des technologies introduites auprès des paysans;
d) améliorer les liaisons de travail entre les agronomes, les agents des services de vulgarisation, les ONG et les organisations paysannes.

Les Essais de Démonstration de Production du Mil

L'objectif visé était de comparer les performances des variétés améliorées à celles des variétés locales.

Matériels et Méthodes

En 1990, la performance des variétés de mil recommandées dans le Centre Sud (Souna 3) et le Centre-Nord (IBV 8004) était comparée à celle des cultivars locaux dans des conditions agronomiques améliorées et dans les systèmes culturaux traditionnels. Le système aux techniques améliorées comportait un écartement de semis de 0,90 m x 0,90 m, un apport (kg/ha) de 60 N, 31 P_2O_5 , 31 K_2O, et un démariage précoce à 3 plants par poquet au 12ème jour après la levée. Le système traditionnel était laissé à l'appréciation du paysan comme à l'accoutumée.

Le dispositif expérimental était un split-plot avec comme parcelles principales les techniques culturales et les variétés dans les parcelles secondaires. La taille des parcelles élémentaires était de 625 m^2. Il y avait cinq paysans dans le Centre Sud et un paysan dans le Centre-Nord. Chaque paysan constituait une répétition.

Résultats et Discussions

Les résultats des essais en milieu paysan ont montré que dans le Centre Sud, régions de Kaolack et Fatick, le Souna 3 et les variétés locales donnaient des rendements respectifs de 1489 et 1281 kg/ha avec des pratiques agronomiques améliorées. Avec la pratique traditionnelle, les rendements de Souna 3 et du cultivar local étaient respectivement de 1033 et 792 kg/ha. Il est évident que le rendement du mil pourrait être considérablement accru si des semences de cultivars améliorés, de l'engrais et autres intrants étaient mis à la disposition des paysans. Le rendement de Souna 3 excédait celui de la variété locale de 28 %, soit respectivement 1261 et 986 kg/ha (Tableaux 1 et 2). Le cultivar de mil des paysans répondait aussi aux techniques agronomiques améliorées comparativement aux pratiques culturales traditionnelles, donnant des moyennes de rendement respectives de 1181 et 792 kg/ha. Les résultats de ces essais de vérification confirment que les rendements des cultivars de mil peuvent être augmentés de 46 pour cent si l'on utilise des pratiques agronomiques améliorées (Tableaux 1 et 3).

Tableau 1. Performance de rendement de la variété de mil Souna 3 et d'un cultivar local avec pratiques agronomiques améliorée et pratiques agronomiques traditionnelles.

Localité	Var. Souna 3		Cultivar local		
	PA	PT	PA	PT	Moyenne de rendement
Soulkou Loyen	1106	725	888	434	788
Darou	1816	1463	1730	1511	1630
Paoskoto	1325	852	1175	804	1039
Diofior	2100	1455	1623	926	1526
Niakhar	1099	651	491	285	636
Rendement moyen intersite	1489	1033	1181	792	1124

PA = Pratiques Agronomiques Améliorées.
PT = Pratiques Agronomiques Traditionnelles.

Tableau 2. Rendements (kg/ha) en grains de mil des essais de démonstration en milieu paysan.

Variété	Centre Sud	Centre Nord
Souna 3	1261 (a)	
IBV 8004		746
Variété locale	986 (b)	784
L.S.D. 05	123	123

N.B. : (a) et (b) veulent dire que les deux variétés sont significativement différentes au seuil de 5 %.

Tableau 3. Rendements (kg/ha) en grains de mil des essais de démonstration en milieu paysan.

Systèmes de culture	Centre Sud	Centre Nord
Techniques traditionnelles	912 (a)	716
Techniques améliorées	1335 (b)	815
L.S.D. 05	189	125

Conclusion

En ce qui concerne la culture du mil (culture pure) dans la région du Centre-Sud, les résultats des essais de démonstration en milieu paysan ont permis de fournir aux paysans les options techniques suivantes:

a) le remplacement des cultivars locaux de mil par le Souna 3, variété améliorée, qui donnait une moyenne de rendement de 1000 kg/ha dans les systèmes traditionnels de culture.

b) le maintien du cultivar de mil local avec utilisation de pratiques agronomiques améliorées, ce qui donnait une moyenne de rendement de 1200 kg/ha.

c) la culture de la variété de mil recommandée Souna 3, avec des pratiques agronomiques améliorées, ce qui donnait une moyenne de rendement de 1500 kg/ha.

La valorisation de la matière organique et du phosphate naturel

Face à la pauvreté des sols et le coût onéreux des engrais minéraux, cette étude visait à déterminer si l'application des engrais minéraux pouvait être réduite en la combinant avec l'apport de fumure organique.

Matériels et Méthodes

L'essai comportant cinq niveaux d'engrais sur le cultivar de mil Souna 3 dans les régions de Kaolack et Fatick et sur la variété de mil IBV 8004 dans les régions de Diourbel et Thiès. Le dispositif utilisé était un bloc de Fisher complètement randomisé en 3 répétitions en milieu paysan. Les traitements sont dans le Tableau 4. Les parcelles élémentaires étaient formées de 12 lignes de 13 poquets chacune.

Résultats et discussion

Au Centre-Sud, la dose d'engrais recommandée (150 kg/ha) dans les villages de Médina Sabakh, Diofior et Soumbel a permis d'obtenir des moyennes de rendement respectives de 1202, 724 et 1893 kg/ha. La moyenne de rendement pour les trois villages a été de 1273 kg/ha. La réduction de la dose d'engrais sus-mentionnée de 50 % accompagnée d'un apport de 2 t/ha d'engrais organique a donné 15 % de rendement de moins, soit 1075 kg/ha (Tableau 4).
Le rendement du mil a généralement été faible lorsque la fumure organique a été utilisée seule. Au Centre-Nord, dans les villages de Ndiémane et Gatt, les applications de 50 % de la dose d'engrais minérale recommandée et de 2 tonnes de fumure organique ont donné les rendements en grain les plus élevés, soit respectivement 1247 et 1260 kg/ha. A travers les localités des trois villages de Thieytou, Gatt et Ndiémane, la moyenne de rendement la plus élevée (1042 kg/ha) a été obtenue par l'application d'une forte dose d'engrais commercial (150 kg/ha de NPK 10-21-21 et 100 kg/ha d'urée) et de fumure organique (Tableau 4). Il ressort des données que la région du Centre-Nord a des sols de fertilité relativement faible.

Tableau 4. Effet de l'engrais minéral et de la fumure organique sur le rendement (kg/ha) du mil dans les différents villages du Sénégal.

Dose de fumure	Médina Sabakh	Dio-fior	Soum bel	Thie-ytou	Ndié-mane	Gatt	Moye n-ne
(i) 150 kg/ha NPK (10-21-21) + 100 kg/ha d'urée	1202	724	1893	923	1097	747	1098
(ii) 150 kg/ha NPK (10-21-21) + 100 kg/ha d'urée + 2 t/ha de fumier	1300	833	2032	661	1497	968	1215
(iii) 2 t/ha de fumier	810	575	1282	407	858	589	754
(iv) 75 kg/ha NPK (10-21-21) + 50 kg/ha d'urée + 2 t/ha de fumier	995	515	1716	458	1247	1260	1032
(v) 4 t/ha de fumier	800	280	1528	377	979	736	783
CV (%)	18,2	31,5	7,4	19,9	22,4	28,3	
PPDS (5%)	326,4	301	235	212	478	475	

En 1993 et 1994; la variété IBV 8004 était remplacée par l'IBMV 8402 et dans le traitement 4, l'engrais minéral était substitué par l'apport de 30 kg/ha de P_2O_5 ou 100 kg/ha de phosphate tricalcique de Taïba. L'essai était conduit chez quatre paysans dans chaque site.

L'apport de 2 t/ha de fumier + 30 kg/ha de P_2O_5 avait donné les mêmes niveaux de rendements que l'application de 2 t/ha de fumier plus 50 % de la fumure minérale vulgarisée. Cela représente légèrement une baisse de 14 % par rapport à la fumure minérale vulgarisée (Tableau 5).

Tableau 5. Rendements (kg/ha) de grains de mil en fonction de différentes doses de fumure minérale, organique et organo-minérale.

Dose de fumure	Thyssé kaymor	Dio-fior	Darou	Ndiémane	Moye nne
1. Témoin sans fumure	627 a	959 a	765	661	755
2. 150 kg/ha de 14-7-7 + 100 kg/ha d'urée	1132 a	1618 a	-	1095	1282
3. 2 t/ha de fumier	610 c	1358 b	975	845	947
4. 2 t/ha de fumier + 30 kg/ha de P2O5	919 b	1616 a	1042	898	1119
5. 2 t/ha de fumier + 50 kg/ha de 14-7-7	855 b	1540 ab	-	1214	1203
Moyenne	829	1418	927	943	
CV(%)	30	22	36	30	
PPDS (5%)	211	258	339	238	

Conclusion

L'apport de 2 t/ha de fumier par rapport aux pratiques paysannes sans fumure procure une plus-value de rendement de 26 %. La production est améliorée de 23 % avec un complément d'application de 50 % de la fumure minérale vulgarisée ou 30 kg/ha de P_2O_5 ce qui représente une légère baisse de 14 % par rapport à la fumure minérale vulgarisée.

L'association culturale mil/niébé

Les recherches conduites entre 1990 and 1993 ont eu pour base de départ les résultats des travaux de Dancette. En effet, Dancette (1976) ayant défini les besoins en eau du mil s'est préoccupé d'une meilleure utilisation des réserves hydriques du sol. L'association culturale mil/niébé paraissait la meilleure solution.

Les résultats des essais menés à Louga et Bambey ont permis à Dancette (1984) de tirer les conclusions suivantes :

1) A Louga, l'association n'est pas la solution rêvée pour lutter avec succès contre la Sécheresse et que donc l'association dans cette zone n'est pas rentable.

2) Bambey constitue une zone limite.

Sur la base de ces résultats, de 1990 à 1992, nous avions installé en station et en milieu paysan (dans les régions de Diourbel, Thiès, Fatick et Kaolack) des essais d'associa-

tion de mil-niébé. C'est ainsi qu'en contre saison 1990 au CNRA de Bambey un essai était implanté dans un système d'irrigation différentielle permettant de simuler la pluviométrie de différentes zones. Cette étude était conduite avec la collaboration du CERAAS (Centre d'Etude de la Résistance à la Sécheresse) (Diangar, 1991). Trois zones étaient définies à partir des quantités d'eau d'irrigation reçues:
- zone sèche : 260-370 mm
- zone moyennement humide : 370-480 mm
- zone humide : 480-660 mm.

Par l'utilisation du coefficient d'équivalence en surface (L.E.R.)*, les résultats montraient que la culture associée mil-niébé était plus rentable que la culture pure du mil ou du niébé du point de vue production des graines. (Tableau 6) plus particulièrement dans la zone de 260-370 mm.

Tableau 6: Rendements en grains (kg/ha) des différents systèmes de cultures dans l'association mil/niébé en contre saison.

Zone de culture	Mil		Niébé		LER
	Mil pur	Mil associé	Niébé pur	Niébé associé	
Zone sèche (260-370 mm)	405	619	722	304	1,95
Zone moyen. humide (370-480 mm)	1035	1132	1452	487	1,43
Zone humide (480-660 mm)	1556	1637	1781	832	1,35

Dans les conditions d'hivernage de 1990 à 1993 (Diangar, 1992, 1993), des essais étaient implantés au CNRA de Bambey et à la station de Nioro pour confirmer les résultats de contre-saison 1990 et déterminer une géométrie de semis pour l'association mil-niébé. Trois variétés de mil (Souna 3, IBV 8004 et IBV 8001) étaient associées à trois variétés de niébé, (Bambey 21, Ndiambour, et 58-74).
Dans les associations, trois géométrie de semis étaient testées:

- mil semé à 100 cm x 90 cm avec le niébé en une unique ligne intercalaire à 50 x 25 cm pour Bambey 21 ou 50 cm x 50 cm pour Ndiambour et 58-74.
- mil semé à 150 cm x 90 cm et le niébé en une double ligne intercalaire à 50 cm x 5 cm pour Bambey 21 ou 50 cm x 50 cm pour Ndiambour et 58-74.
- mil semé à 150 cm x 60 cm et le niébé (Ndiambour, 58-74) à 50 cm x 50 cm.

A Bambey, l'association mil-niébé combinant le mil IBV 8004 avec le niébé Ndiambour (variété grainière) ou le niébé 58-74 (variété fourragère) à une géométrie de semis de doubles lignes de niébé entre les lignes de mil de semis 1m50 x 0,60m s'adapte bien à la zone (LER = 1,21).

* L.E.R. ou coefficient d'équilavence en surface se définit de la façon suivante:

$$\text{L.E.R.} = \frac{\text{Rendement de A en association}}{\text{Rendement de A en culture pure}} + \frac{\text{Rendement de B en association}}{\text{Rendement de B en cult. pure}}$$

où A représente la première culture (mil) et B la seconde culture (niébé).

A Nioro, l'association mil-niébé Souna 3 x Bambey 21 avec une géométrie de semis d'une ligne de niébé entre les lignes de mil aux écartements de semis 1m x 0,90m donnait les meilleurs rendements (LER = 1,54).

Dans ces deux situations, on notait une supériorité des rendements en grains de mil de l'association mil/niébé par rapport à la culture pure de mil. Le gain de rendement s'élevait de 9 % à Bambey et 32 % à Nioro.

Matériel et Méthodes

En 1992, nous avons testé en milieu paysan les meilleures géométries de semis obtenues en station (Diangar, 1993). Les essais étaient implantés au niveau de 12 sites dans les régions de Kaolack (4), Fatick (4), Diourbel (2) et Thiès (2) en culture pluviale. Les essais étaient réalisés avec la collaboration du PNVA (Programme National de Vulgarisation Agricole) et de l'ONG Rodale International. Pour le mil, le Souna 3 était utilisé pour les régions Kaolack-Fatick et IBV 8004 pour Diourbel-Thiès. Deux variétés de niébé {Ndiambour pour la production en grains et 58-74 pour la production de fanes (fourrage)} étaient utilisées.

L'association mil-niébé avec le mil associé aux écartements 100 cm x 60 cm (régions de Fatick-Kaolack) ou 150 cm x 60 cm (régions de Diourbel-Thiès) à une unique ligne intercalaire (régions de Fatick-Kaolack) ou une double ligne intercalaire (régions Diourbel-Thiès) de niébé à 50 cm x 50 cm étaient comparée aux cultures pures :
- mil pur à 90 cm x 90 cm
- niébé pur à 50 cm x 50 cm.

Résultats et Discussions

Les résultats étaient les suivants:

- Centre Sud (Régions de Kaolack-Fatick): les rendements en grains du mil dans les associations représentaient 80 % des rendements du mil en culture pure. La production de grains de niébé était faible. La production de fanes était néanmoins bonne avec le niébé fourrage 58-74 avec un rendement de 1400 kg/ha de fanes.

- Centre Nord (Régions de Diourbel-Thiès): les rendements du mil en culture pure étaient supérieurs à ceux du mil associé. Les rendements du mil obtenus dans l'association mil x Ndiambour étaient légèrement supérieurs à ceux obtenus dans l'association mil x 58-74.

Les rendements en grains de mil obtenus dans les associations sont de l'ordre de 80 % à 90 % des cultures pures dans les essais d'association mil/niébé de 1992 reconduits en 1993 à Diofior et Ndiamsil. A Ndiamsil comme à Diofior, le rendement du mil grain était plus élevé dans l'association du mil grains avec le niébé grainier. Cependant, du point de vue économique l'association mil/niébé avec le niébé fourrager 58-74 est plus rentable (Tableau 7).

Tableau 7. Bénéfice (F CFA) obtenu de l'association mil/niébé par rapport aux cultures pures de mil et de niébé.

Type d'association mil/niébé	Ndiamsil		Diofor	
	Mil pur IBMV 8402	Niébé pur	Mil pur Souna 3	Niébé pur
Association avec le niébé fourrager 58-74	295	37 117	7 307	40 369
Association avec le niébé grainier Ndiambour	14 270	8 950	18 607	4 835

Les résultats obtenus à Ndiamsil et à Diofior ont montré que les paysans qui cultivent du niébé fourrager en culture pure augmentent leur revenu en adoptant l'association mil/niébé fourrager. Cependant, les paysans qui pratiquent la culture pure du mil sont majoritaires dans ces zones. Toutefois, il est possible d'améliorer avec une plus-value de 14 000 F à 18 000 F respectivement à Ndiamsil et à Diofior (Tableau 7). Au niveau des deux sites, les paysans souhaiteraient disposer dans les associations d'une variété doublement performante aussi bien en fourrage qu'en grains.

Conclusion

Les essais sur l'association mil/niébé ont permis de définir des géométries de semis qui donnent 80 % du rendement du mil en culture pure avec une production supplémentaire de fanes de niébé qui est de l'ordre de 1400 kg/ha pour 58-74 et une production assez importante de grains de niébé pouvant dépasser 200 kg/ha.

La formation des agents techniques et des paysans aux techniques de compostage

L'objectif visé était de former les agents des inspections régionales de l'Agriculture et les paysans aux techniques modernes de compostage et de fabrication de fumier amélioré pour une meilleure gestion du fumier et des résidus de récolte; et de produire suffisamment du fumier de qualité et de compost pour les essais.

Calendrier d'exécution

- Avril-Mai 1993 : construction de cinq fosses compostières de 9 m³ (3m x 2m x 1,5m) à Diofior (2), Ndiémane (1), Bambey (1), Thilmakha (1).

- Mai 1993 : séminaire de formation des agents des inspections régionale organisé conjointement avec le PNVA.

- Décembre 1993-Mars 1994 : formation des paysans. Les fosses construites ont servi de démonstration pour le compostage.

Les paysans sont venus nombreux assister à la formation où on a enregistré une participation de plus de 50 paysans dans chaque site. Il y avait aussi des groupements de paysans venant des autres villages. A ces séances de formation, ont participé les collègues du programme Gestion des Ressources Naturelles de l'ISRA (Service Fertilisation) et les spécialistes de l'ONG Rodale International. Les formations se sont poursuivies en 1995.

Enquêtes spécifiques sur les pratiques culturales du mil

Les enquêtes effectuées en 1990 en milieu paysan établissent le constat que le taux d'adoption des variétés améliorées était faible et était de l'ordre de 5 à 10 % (Diangar, 1990). Après deux à trois années d'expérimentation, il était important de suivre l'évolution des variétés améliorées au niveau des sites d'essais. C'est ainsi que les enquêtes menées en 1994 dans les villages de Ndiamsil, Ndiémane et Diofior ont fait apparaître un taux d'adoption des variétés améliorées de 37 à 65 % par rapport aux surfaces emblavées et à la quantité de semences utilisées. Les enquêtes portaient sur un échantillon de 50 paysans dans chaque village (Tableau 8). La variété améliorée la plus utilisée est le Souna 3 qu'on retrouve à Ndiémane et Ndiamsil même si elle n'est pas recommandée pour cette zone.

Tableau 8. Utilisation des variétés de mil en milieu paysan sur un échantillon de 50 paysans.

Village	Quantité de semences (kg)		Surfaces emblavées (ha)	
	Variété locale	Variété améliorée	Variété locale	Variété améliorée
Diofior	295	305	100	105 (51)*
Ndiamsil	193	286	100	184 (65)
Ndiémane	397	233	118	68 (37)
Total	885	-	318	357
% Variété améliorée	48		53	

* Les chiffres entre parenthèse indiquent les superficies occupées par la variété améliorée sur les surfaces totales emblavées.

Conclusions Générales

Ce financement du SAFGRAD nous a permis d'une part de raffiner nos résultats de recherche et d'autre part de renforcer nos liens avec nos partenaires du développement et les organisations paysannes. Le financement nous a permis particulièrement:

- d'avoir une meilleure connaissance des exploitations paysannes;

- d'obtenir des résultats satisfaisants sur les géométries de semis de l'association mil/niébé ;

- de montrer l'intérêt de l'apport du fumier qui donne une plus-value 26 % par rapport aux pratiques paysannes sans fumure dont le rendement est amélioré de 23 % avec un complément de phosphore;

- de susciter l'engouement des paysans dans la fabrication du compost. Il est certain qu'un effet supplémentaire de sensibilisation et de formation doit être fourni pour l'adoption de la technologie.

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Technologies Disponibles pour l'Accroissement de la Production des Systèmes Culturaux à Dominante Mil au Niger

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Résumé

Les systèmes culturaux au Niger sont, à plus de 80% à dominante mil associé à d'autres cultures. L´association des cultures à base de mil est une pratique utilisée depuis fort longtemps par les paysans Nigériens. Elle vise à sécuriser les producteurs en cas de calamités naturelles. Des travaux de recherche ont été faits en vue d'améliorer cette pratique. Ces travaux ont permis de finaliser, en milieu paysan, des technologies pouvant permettre d'accroître de manière substantielle la productivité des systèmes mil/sorgho et mil/niébé.

Une étude a été conduite en 1990 et 1991 avec 10 paysans de Sokondji Birni et en station de Tara en zone soudano-sahélienne avec pour objectif l'Amélioration de la productivité du système mil/sorgho. Il ressort de cette étude que: la pratique d'association permet d'avoir une production globale de plus de 1.5 tonne à l'hectare; pour le mil, on ne peut pas augmenter le rendement en manipulant uniquement le peuplement et la variété par rapport à la pratique paysanne. Toutefois, une augmentation pouvant atteindre 60% est possible avec un apport d'éléments fertilisants. Quant au rendement sorgho, il peut être amélioré de plus de 50% en jouant sur le peuplement à l'hectare; cette amélioration peut atteindre 125% voire plus si des éléments fertilisants sont apportés en supplément. Les paysans et les vulgarisateurs ont apprécié cette approche de la recherche qui prend en compte leurs pratiques et soucis majeurs de production.

En 1993 et 1994, une autre étude a été conduite au niveau de trois villages avec 22 paysans en zone sahélienne en vue de vérifier l'adaptabilité des recommandations de la recherche sur les systèmes d'association mil/niébé. Il ressort que l'effet variétal mil est perceptible surtout au niveau des sites de la zone à faible pluviométrie (+20% de rendement grain). Pour les autres sites, la variété améliorée (Zatib) est très appréciée par les paysans pour certaines caractéristiques (taille et compacité des épis, tolérance à la mineuse de l'épi). L'augmentation de la densité agit positivement sur les rendements au grains au niveau des trois sites avec un gain de 9%, 28.5% et 20.6%, respectivement. Pour le niébé, l'effet variétal de la TN5-78 est significatif avec un gain en rendement-grains de 29%, 42.8% et 9% au niveau des trois sites respectivement. La production en graine du niébé s'est sensiblement améliorée par un accroissement de 36% grâce à l'adoption de nouvelles techniques culturales (densité et géométrie de semis) et sans apport d'engrais. L'apport d'engrais combiné aux traitements phytosanitaires permet une augmentation nette de production de 62%, 59% et 186%.

Abstract

Cropping systems in Niger are for more than 80% based on millet grown in mixture with other crops. Millet-based intercropping has been for long a farmer's practice in Niger. It is designed to ensure security for producers in case of natural disasters. Research was conducted in order to improve such a practice. Technologies tested on farm were found to substantially to contribute in inceasing the productivity of millet/sorghum and millet/cowpea based systems.

A study was conductd in 1990 with 10 farmers in Sokondji Birni and on Tara station in the Sudan-sahel zone with the objective of improving the productivity of the millet/sorghum-based system. It revealed that : intercropping can yield a total production of more than 1.5t/ha; millet yield cannot be increased by oly manipulating plant stand and variety in relation to farmer's practices. An increase of up to 60% is possible however with addition of fertilizers. Sorghum yield may in contrast be improved by more than 50% when plant stand is manipulated, with increase reaching 125% or more if fertilizers are applied. Farmers and extension workers appreciated this research approach which takes into account their practices and major production concerns.

In 1993 and 1994, another study was conducted in three villages with 22 farmers in the sahel zone in ordr to verify the adaptability of the recommendations of the research on the millet/cowpea intercropping systems. The study showed that millet variety effect is noticeable particularly in the sites of the low rainfall zone (+20% grain yield). In the other sites, the improved variety (Zatib) is lighly appreciated by farmers for some characteristics (ear size and compacity, tolerance to ear borer). Increase in density has a positive effect on grain yields in the three sites, with a gain of 9%, 28.5% and 20.6% respectively. For cowpea, TN5-78 variety effect is significant with a grain yield gain of 29%, 42.8% and 9% respectively in the three sites. New cropping techniques (density and planting arrangement) without fertilizers application substantially increased by 36% the cowpea grain yield. Fertilizer application combined with phytosanitary treatments may result in a net production increase of 62%, 59% and 186%.

Introduction

L'association de deux, trois ou même quatre cultures en même temps est assez fréquente au Niger. Cependant, les types d'associations les plus rencontrés sont mil-niébé, mil-arachide, mil-sorgho et sorgho-arachide. On y rencontre aussi l'association à trois niveaux comme mil-sorgho-niébé et mil-sorgho-arachide et même à quatre niveaux tels que mil-sorgho-arachide-niébé. Par exemple en 1990, la culture pure du mil n'occupe que 35.52% de la superficie totale emblavée en mil; soit 4.000.845 ha (Anonymes, Ministère de l'Agriculture et de l'Elevage, 1991).
Par la pratique de la culture associée, les paysans visent cinq objectifs principaux :

1) une diminution des risques,
2) un complément alimentaire,
3) une augmentation de la production,
4) commercialisation (c'est à dire obtenir de l'argent liquide sans réduire leurs stocks de production alimentaire),

5) une meilleur utilisation de la main d'œuvre.

Parmi tous les effets bénéfiques reconnus à l'association des cultures, la minimisation des risques liés à la production agricole est certainement le plus important dans les pays arides et semi-arides.
La recherche sur les cultures associées a commencé au Niger depuis 1963 à Tarna par l'IRAT (Roesch 1982, Reddy et al., 1985). Elle a reçu un regain d'intérêt à l'INRAN à partir de 1983 avec la demande de nouvelles technologies pour l'association des cultures par la vulgarisation. Ces études ont été surtout axées, pour un début, sur l'association mil-niébé parce que la plus pratiquée dans tout le pays. Ces travaux ont été plus approfondis et visaient à mieux comprendre les systèmes de cultures associées pour pouvoir manipuler quelques facteurs importants, tels que la densité de semis, la date de semi, le cycle des cultures en association, etc.. Chacun de ces facteurs en combinaison avec la pluviométrie et la fertilité du sol joue en effet un rôle important dans la détermination d'un système de cultures plus performant selon les conditions de production.

En 1988, la synthèse de différents résultats a permis la mise au point des recommandations sous forme de fascicule intitulé 'Stratégies alternatives pour la production du mil et du niébé en hivernage'. Les stratégies alternatives manipulent les systèmes culturaux de manière à les adapter aux périodes d'installation des campagnes d'hivernage et alors aux périodes de semis. Un autre objectif est aussi de rompre avec les pratiques du passé en proposant plusieurs options aux utilisateurs en fonction de leur capacité à disposer ou non des intrants.

D'autres travaux de recherche en station, ont montré des possibilités d'augmentation de la productivité des systèmes associés mil/sorgho et mil/arachide.
Le présent document présente les résultats de deux types d'expérimentations en milieu paysan, sur les systèmes associés mil/sorgho et mil/niébé conduites, respectivement en 1990 et 1991; et en 1993 et 1994, grâce au soutien financier du SAFGRAD/BAD et du ROCAFREMI/Coopération Suisse au développement.
Les objectifs de ces expérimentations sont les suivants :

- Tester l'adaptabilité des recommandations dans les conditions du producteur;
- Obtenir le feed-back des vulgarisateurs et des agriculteurs par rapport aux recommandations proposées par la recherche.

Matériels et Méthodes

A) Système Mil/Sorgho

A.1) <u>Site Expérimental</u>

Le village de Sokondji Birni a été retenu comme site expérimental parmi les cinq villages échantillons ayant fait l'objet d'enquêtes socio-économiques de base. Il comprend 31 exploitations composées de 296 personnes dont 70 hommes (24%), 90 femmes (30%) et 136 enfants de moins de 15 ans (46%). La taille moyenne d'une famille par exploitant est de 10 personnes et exploite cinq champs d'une superficie de 5 ha. Le nombre moyen d'actifs agricoles est de six par exploitation dont deux hommes. Les femmes et les enfants ne participant qu'au semis et à la récolte, d'où un problème de main d'oeuvre au moment des travaux d'entretien. La culture attelée existe (7 unités de culture attelée pour les 11 exploitations) mais elle n'est utilisée que pour le labour (Ibro, 1991). Les chefs d'exploitation font recours à la main d'oeuvre salariale pour les travaux d'entretien. Les principales activités économiques sont l'agriculture et l'élevage; mais le petit commerce et l'artisanat sont aussi pratiqués par les femmes.

Le climat est de type soudano-sahélien avec une pluviométrie moyenne de 800 mm en 60 jours, c'est l'une des régions les plus arrosées du Niger. Les températures oscillent entre17.8°C minima en Décembre et Janvier, et 40.54°C maxima en mars-avril et parfois en mai. La moyenne des températures est de 28.71°C en l'insolation de 3015,13 h/an soit 8.26 h/j (Station Météo Gaya, 1990). La pluviométrie enregistrée en 1990 est de 652,9 mm en 47 jours et 764.4mm en 51 jours en 1991 à Sakondji, Birni. Elle est de 651.4mm en 38 jours en 1990 et 796.2mm en 49 jours en 1991 à Tara. Pour les deux années de conduite de l'expérimentation, les essais sont pour la plupart placés sur des sols à texture sableuse avec une faible proportion d'argile et de limon (voir Tableau 1).

Tableau 1. Caractéristiques des sols des sites des essais (moyennes) des champs.

	E.M.R	TARA
Granulométrie		
Sables (%)	88.90	83.40
Argiles (%)	4.40	8.20
Limons (%)	6.70	8.40
Analyse Chimique		
pH (H20)	6.4	5.2
P assimilable (ppm)	3.89	2.53
N total (%)	0/017	0.029
CEC meq/100g	2.82	1.49
Matière organique (%)	0.41	0.30

légende: *Essai en milieu Réel (EMR)

A2) <u>Dispositif expérimental</u>

Le dispositif utilisé est en blocs complets randomisés avec 4 répétitions en station et une répétition/champ chez les onze (11) paysans volontaires. La taille des parcelles élémentaires est de 216 m². Les cinq options technologiques (traitements); en étude sont:

T_1: Pratique traditionnelle d'association mil-sorgho

- Variété de mil : locale.
- Date et système de semis comme dans les champs des paysans.
- Pas d´engrais minéraux.

T_2: Pratique traditionnelle améliorée

$T_2 = T_1$ +engrais minéraux (20 kg/ha de P_2O_5 et 46 kg/ha N apportés au mil et au sorgho).

T_3: Paquet technologique non monétaire

- Variété de mil : CIVT
- Variété de sorgho BKC
- densité de mil 1,50m x 0,75m
- Densité de sorgho : 1,50m x 0,75m (1 ligne de sorgho alternée avec 1ligne de mil (1:1)
- Date de semi du sorgho : 10-14 jours après le mil
- Pas d´engrais minéraux

T_4: Paquet technologique avec intrants limités

- Variété de mil : CIVT
- Variété de sorgho : BKC
- Densité de mil: 1,50m x 0,50m (mil/sorgho 1:1)
- Densite du sorgho: 1,50mx0,50m (mil/sorgho 1:1)
- Date de semis du sorgho: 10 - 14 jours après le mil
- Engrais minéraux: 20kg/ha de P_2O_5 apportés au mil et au sorgho

T_5: Paquet technologique complet

$T_5 = T_4$ + 46 Kg/ha N en deux apports fractionnés sur le mil et le sorgho.

A3) Opérations culturales

Les semis ont été effectués manuellement. En 1990, le semis du mil a été fait entre le 16 et 21 Mai et du 17 Mai tandis que le sorgho l'a été du 1er au 2 Juin.
Pour le système traditionnel, les géométries et densité de semis ont varié d'un paysan à un autre.

Tableau 2. Densités et peuplement à l'hectare.

Ecartements	N traitements		Nombre de poquets/ha	
	Mil	Sorgho	Mil	Sorgho
1er système	0,93 m x 1,35 m	1,86 m x 1,35 m	8426	4212
T1 et T2				
2ème système	0,93 m x 1, 35 m	0,93 m x 1, 35 m	8426	7824
T3	1,50 m x 0, 75	1, 50 m x 0,75 m	8888	8755
T4 et T5	1,50 m x 0, 50 m	1, 50 m x 0,50 m	13333	13200

NB: - 1er Système : lignes de mil pur alternées aux lignes de mil-sorgho (1m : 1ms)
- 2ème système : lignes de poquet alternés de mil et de sorgho (1ms : 1ms).

Les sarclages ont été faits manuellement avec la daba dans la plupart des cas et la hilaire rarement. Ils sont exécutés pour la plupart des cas par la main d'œuvre salariale. Un démariage à trois plants par poquet de mil et de sorgho a été fait au niveau des traitements 3, 4, et 5. Ce nombre est jugé faible par les paysans qui ont fait un démariage variant de 4 à 7 plants pour les traitements 1 et 2, c'est-à-dire ceux correspondant à leurs propres pratiques. Ce travail est surtout fait au moment du 1er sarclage.

L'urée sur le mil et le sorgho a consisté en deux apports fractionnés à la dose de 100Kg/ha pour chaque culture suivant les traitements. Cette application est localisée et suivie d'un enfouissement sur toutes les parcelles concernées, sauf pour le T_2 où l'application est laissée au soin des paysans qui dans la plupart des cas l'ont épandu à la volée et parfois en localisation.

B) Système Mil/Niébé

L'étude a été conduite en 1993 et 1994 au niveau de trois villages avec 22 paysans en zone sahélienne, où la pluviométrie varie de 400 à 550 mm, en vue de vérifier l'adaptabilité des recommandations de la recherche. Le dispositif expérimental utilisé est celui des blocs complets randomisés avec une seule répétition par champ au niveau de 3 localités, N'Dounga, Tollo et Téra. Le nombre des paysans varie de 6 à 10 par site. Les dimensions des parcelles sont de 24m x 12m = 288 m^2

Les traitements par site sont comme suit :

T_1 Contrôle : Pratique traditionnelle

Les variétés utilisées; mil et niébé sont celles des paysans. De même que toutes les pratiques culturales (date de semis, densité, non apport d'engrais minéraux, etc...).

T_2 Pratiques améliorées (intrants non monétaires)

Seules les variétés utilisées changent par rapport au traitement T_1. Les variétés utilisées sont le Zatib (H80-10-GR à Téra) pour le mil; TN5-78 pour le niébé.

T_3 Pratiques améliorées (intrants limités)

Phosphore (100 Kg/ha de SSP sans urée); variété Zatib (H-80-10-GR) pour le mil; variété TN5-78 pour le niébé avec semis du niébé : 7-14 jours après le semis du mil; géométrie-semis du mil : 1,50m x 0,75m; géométrie semis du niébé : 1,50m x 0,75m.

T_4 Pratiques améliorées (paquet complet)

$T_4 = T_3$ + apport de fumure azotée (46Kg N/ha)

Pour ces types d'essai, leur évaluation par les paysans et les agents de développement est aussi important que les rendements obtenus. C'est pourquoi des fiches d'évaluation des essais ont été soumises aux supperviseurs des essais. Ce feed-back permettra de juger de l'opportunité d'apporter ou non des modifications aux essais et aux conditions de leur réalisation.

Résultats et Discussions

A) Système Mil/Sorgho

A1) <u>Tallage</u>

Le tallage étant un élément determinant du rendement, un comptage de nombre de talles a été effectué deux semaines après le démariage à trois plants par poquet. La productivité de ces talles a été calculée à partir du nombre d´épis récoltés par poquet. Les résultats de ces observations sont résumés dans le Tableau 3 (Annexe N°1). Une comparaison entre les traitements traditionnels et les traitements améliorés est très difficile car les paysans n'ont pas respectés le démariage comme il a été conseillé.
Pour le sorgho; il n'a pas été observé des talles au niveau de tous les sites en 1990. Mais en 1991, il a été constaté dans des rares cas des talles qui du reste n'ont pas été productifs.

Tableau 3. Nombre de talles végétatifs et productifs du mil par poquet en 1990, 1991 en milieu paysan et en station (rendement en kg/ha).

Traitements	Champs paysans (EMR)				Station de Tara			
	1990		1991		1990		1991	
	Végétatifs	Productifs	Végétatifs	Productifs	Végétatifs	Productifs	Végétatifs	Productifs
1	16	4	17	4	14	4	12	4
2	17	4	19	5	24	6	14	6
3	12	3	10	4	9	3	9	2
4	13	3	11	4	13	4	11	3
5	13	4	12	5	15	5	12	4
PPS (5%)	10,40	17,45	11,82	16,88	16	17	15,2	12,5
CV(%)	1,35	1,52	1,57	1,49	3,7	1,5	3,8	1,8

A2) <u>Attaques et parasitisme</u>

En 1990, des attaques ont été observés sur les cultures. Ce sont d'abord des chenilles défoliatrices qui ont provoqué des dégâts sur les jeunes plants de mil et surtout du sorgho à un moment de sécheresse. Ces attaques ont disparu avec le retour des pluies. Au stade floraison du mil, les essais qui étaient les seuls à ce stade ont subi des attaques des punaises (*Dysdercus volkeri* et *Rhyniptia infuscata*) et quelques cantharides qui ont causé l'avortement des fleurs et sucé les grains laiteux. Pour combattre ce fléau, un traitement au Karaté 0,80% ULV à la dose de 2,5 l/ha à l'atomiseur portatif micron ULVA 116 a été appliqué.

Il y a eu aussi quelques attaques d'oiseaux granivores (genre moineau doré) sur les épis du mil à maturité. Pour les chasser, les paysans ont eu recours à des moyens traditionnels tels que épouvantail, frondes, cris, etc.

A3) Rendements et composantes des rendements

Les rendements obtenus tant pour le mil que pour le sorgho (voir tableaux 4-5, Annexes n° 2-3), au cours des deux années sont supérieurs aux moyennes de l'arrondissement de Gaya qui sont de 551 Kg/ha et 305 Kg/ha, respectivement pour le mil et le sorgho (Anonymes, MAG/EI Direction des statistiques agricoles, 1991). En 1990, le rendement en grains et en matière sèche est meilleur sur les traitements ayant reçu les engrais. La production du mil est significativement supérieure à celle du sorgho à tous les niveau de traitements. Nous constatons une meilleure performance des variétés locales par rapport au CIVT indépendemment du fait que les traitements ont bénéficié des mêmes techniques d'application. Ceci peut être dû au fait des attaques subies par le CIVT par les punaises *Dysdercus volkeri* et *Ryniptia infuscata* et les cantharides.

Quant au sorgho, on remarque une meilleure performance des traitements améliorés par rapport aux traitements d'ordre pratique paysanne. Ceci est dû aux effets combinés de traitement de semences, densité, et fertilisation.
Les comparaisons se limiteront aux systèmes de culture. En effet, on ne peut pas juger les variétés ou les densités séparément. La différence au niveau de la levée, par exemple, ne peut être attribuée à la seule qualité des semences sans tenir compte de l'effet dû aux traitements 'fongicide' des semences avant semis. Contrairement à ce que pensent les paysans la densité de semi n'a pas affecté de façon significative le tallage du mil. C'est plutôt les engrais qui ont influencé le tallage et le cycle des cultures.

L'augmentation de la densité et changement de variétés (T3 par rapport à T1) n'a eu que peu d'effets positifs pour le sorgho, mais aucun effet pour le mil, au cours des deux années, du fait certainement que les deux céréales ont besoin d'éléments nutritifs alors que les sols en étaient dépourvus. Les densités, pour le mil chez les paysans sont appropriées, compte tenu du niveau relativement faible de fertilité de leurs sols.

Avec l'apport de phosphore et de l'azote, la performance du traitement traditionnel (T_1 par rapport à T_2) pour le mil, est triplée en station mais augmentée seulement de 40% en milieu paysan du fait sans doute de l'hétérogénéité des champs. On retrouve la même tendance au niveau des traitements améliorés où le T_5 a produit trois fois plus que le T_3 en station et 80% de plus en milieu paysan.

L'apport du phosphore seul (T_3 par rapport à T_4) a amélioré de façon significative la production du mil en station et en milieu réel; Ceci serait sans doute dû à la faible teneur en Phosphore assimilable du sol (4ppm). En comparant les traitements T_2 et T_5, qui ont reçu les mêmes doses d'azote et de phosphore, on remarque que le traitement amélioré (T_5) a produit 40% de plus et 10% de moins que le traitement traditionnel amélioré (T_2), respectivement en station et en milieu paysan.

Pour le sorgho, le traitement T_5 a produit dans tous les cas plus que le traitement T_2, 30% et 15% de plus respectivement en station et en milieu paysan. Cette différence s'expliquerait sans doute par la différence de peuplement qui existe entre ces traitements.

En 1990, les traitements ont eu peu d'effet positif sur le mil; cela est probablement attribuable à la différence des dates de semis entre le milieu paysan (16 Mai) et la station (18 Juin).
Le CIVT ayant été plus précoce que la variété locale, a fleuri le premier, dans la zone, et a subi de ce fait beaucoup plus des dégats des punaises *Dysdercus volkeri*, des *Rhyniptia infuscata* et des Cantharides qui ont fait avorter les fleurs et sucer le contenu des grains laiteux malgré les traitements. Le fait qu'il ait eu plus d'attaques des épis par les oiseaux granivores en milieu paysan qu'au niveau de la station, permet d'expliquer outre mesure l'obtention de meilleurs indices de récolte en station par rapport au milieu paysan.

Dans tous les cas, la pratique d'association de cultures permet d'avoir une production globale plus importante et plus sécurisante (Tableau 4) que dans les conditions de monocultures à proprement parler.

L'introduction du niébé comme culture de relais au niveau des traitements T_1 et T_3 a donné une production grains moyen de 75 Kg/ha et 105 Kg/ha respectivement. La production a été plus appréciable en fanes de niébé qui est de 1125 Kg/ha et 875 Kg/ha. La variété locale a produit beaucoup plus de fanes que la TN5-78, mais moins de grains. La faible production en grains s'explique par le fait que le niébé nécessitait plus de travail d'entretien qui malheureusement n'a pas été respecté par certains paysans. L'introduction de cette innovation a été faite à la demande des paysans et des vulgarisateurs ainsi que sur la base de certains travaux de l'ICRISAT en la matière.

Les difficultés pouvant influencer l'adoption des technologies par les paysans ont été relevées au cours de ces deux années d'étude. Elles sont surtout d'ordre socio-économiques. Le code foncier traditionnel fait des terres la propriété des chefs des villages qui peuvent retirer et redistribuer les champs qui n'ont pas été mis en valeur deux campagnes de suite. Ce qui entraine les producteurs à semer des superficies qu'ils ne peuvent pas exploiter en totalité. Conséquence, les paysans sont très occupés par les activités sur tous les champs qu'ils possèdent;

- manque des moyens financiers;
- chèreté des labours (10 000 à 12 000F CFA/ha);
- manque des intrants agricoles comme les fongicides et les engrais (urée principalement) à cause de la rupture du stock de l'Union Sous Régional des Coopératives (USRC) due aux impayés;
- insuffisance de main d'œuvre au moment des sarclages dont est dispensée la majorité de la population concernée qui est composée de femmes et d'enfants. D'où le recours à la main d'oeuvre salariale qui est rare dans la région et par conséquent chère (700 à 1000 F CFA plus 2 à 3 repas la journée du travail);
- effort de maintien de fertilité du sol est très faible car l'utilisation de la fumure minérale est presque inexistante et celle de la fumure organique très timide par manque de temps et de moyens de transport pour quelques paysans collaborateurs.

B) Système Mil/Niébé

Les résultats des essais sont présentés dans le Tableau n°5. D'après ces résultats on remarque que:

- l'effet variétal (T_1 comparé à T_2) n'est perceptible qu'au niveau des sites de Téra dans la zone à faible pluviométrie où la variété H80-10-GR a été légèrement plus productive que la variété locale (795 Kg/ha contre 729 Kg/ha. Mais la variété Zatib est tout de même très appréciée par les paysans pour la taille et la compacité de ses épis et sa relative tolérance vis-à-vis de la mineuse de l'épi. Il y a une grande demande de cette variété au niveau de tous les sites.
- l'effet d'amélioration de techniques par l'augmentation de la densité (T_2 comparé à T_3) est positif au niveau de tous les sites avec un gain de rendement de 9%, 28,5% et 20,6% respectivement à N'Dounga, Tollo et Téra.

- pour le niébé, l'effet de la variété TN5-78 (T_1 comparé à T_2) est significatif avec un gain en rendement grains de 29%, 42,8% et 9% respectivement à N'Dounga, Tollo et Téra. La production en grains du niébé est améliorée de 36%, 23% et 68% sans apport d'engrais grâce à l'adoption de nouvelles techniques culturales (densité et géométrie de semis) (T_2 comparé à T_3);

- l'apport d'engrais et de traitement phytosanitaire permet un gain de production de 62%, 59% et 186% au niveau des 3 sites (T_2 par rapport à T_4).

Globalement nous pouvons dire que les objectifs des essais sont atteints. La majorité des paysans ont apprécié le système de l'association qui est en fait une pratique très ancienne à laquelle ils ont recours pour diversifier, sécuriser et augmenter leur production. De même les chefs de district agricole, collaborateurs malgré leur programme chargé, ont souhaité la continuation des essais. Les uns et les autres ont fait des propositions constructives pour les campagnes à venir.

Tableau 4. Rendements (kg/ha) grains et matière sèche du mil en 1990 et 1991 en milieu paysan et en station.

Traitement	Champs paysans (E.M.R.)						Station de Tara					
	Grains		Matière sèche		Indice de récolte*		Grains		Matière sèche		Indice de récolte*	
	1990	1991	1990	1991	1990	1991	1990	1991	1990	1991	1990	1991
1	860	660	1960	2380	0,29	0,28	390	530	1600	2290	0,24	0,17
2	1200	1040	4030	3250	0,30	0,32	1150	560	3060	3450	0,38	0,16
3	600	620	2280	2190	0,28	0,29	540	390	1780	2570	0,30	0,15
4	740	890	2860	2740	0.26	0,33	1400	510	3780	3230	0,37	0,16
5	1080	1150	3970	3310	0.28	0,31	1600	610	4540	3890	0,35	0,16
PPDS (5%)	120	145	406,5	443	0,045	0,044	250	85	580	510	0,068	0,023
CV (5%)	14,84	17,26	13,91	16,63	15,23	14,91	16	11,12	13	10,74	12,72	9,27

Légende: * Indice de récolte=poids grains/poids matière sèche totale.

Tableau 5. Rendements (kg/ha) grains et matière sèche de sorgho en 1990 et 1991 en milieu paysan et en station.

Traitement	Champs paysans (E.M.R.)						Station de Tara					
	Grains		Matière sèche		Indice de récolte*		Grains		Matière sèche		Indice de récolte*	
	1990	1991	1990	1991	1990	1991	1990	1991	1990	1991	1990	1991
1	280	250	1400	1340	0,21	0,21	240	240	1700	1830	0,14	0,14
2	630	440	2430	2100	0,26	0,23	720	520	3670	3435	0,20	0,15
3	420	370	1680	1670	0,26	0,23	330	370	1500	1990	0,22	0,20
4	580	600	2190	2380	0,27	0,26	670	530	2220	3130	0,25	0,17
5	715	700	2920	3310	0.25	0.30	940	600	3320	3560	0,28	0,17
PPDS (5%)	120	99	410	427	0,286	0,049	210	46	640	448	0,069	0,021
CV (5%)	25	21,82	21	22,35	14,92	20,75	23	6,59	7	10,45	19,12	8,51

Légende: * Indice de récolte = poids grains/poids matière sèche totale.

Tableau 6: Effet de l'association sur la production en grains en 1990 et 1991 en milieu paysan et en station (rendement en kg/ha).

Traitement	Champs paysans (E.M.R.)						Station de Tara					
	1990			1991			1990			1991		
	Mil	Sorgho	Mil Sorgho	Mil	Sorgho	Mil Sorgho	Mil	Sorgho	Mil Sorgho	Mil	Sorgho	Mil Sorgho
1	860	280	1140	660	250	910	390	240	630	530	240	770
2	1200	630	1830	1040	440	1480	1150	520	1870	560	520	1080
3	600	420	1020	620	370	990	540	370	870	390	370	760
4	740	580	1320	890	600	1490	1400	530	2070	510	530	1040
5	1080	715	1795	1150	700	1850	1600	600	2540	610	600	1210
PPDS (5%)	120,5	120	-	145	99	-	250	210	-	510	46	-
CV (5%)	14,84	25	-	17,26	21,82	-	16	23	-	10,45	6,59	-

Tableau 7. Rendements des essais association mil/niébé en milieu paysan, 1993 et 1994.

Localités /Traitements	N'Dounga				Tollo				Tera	
	1993		1994		1993		1994		1994	
	Mil	Niébé	Mil	Niébé	Mil	Niébé	Mil	Niébé	Mil	Niébé
T1 Système local	580	100	1309	449	505	150	947	292	729	202
T2 Système local avec variétés améliorées	434	160	1120	579	415	170	690	417	795	220
T3 Système amélioré sans engrais	620	210	1216	787	590	180	886	513	959	370
T4 Système amélioré avec engrais	950	240	1708	937	835	225	1242	661	1171	630
PPDS (5%)	244	83	452	85	210	92	234	43	247	139
CV (5%)	27,38	47,8	9,5	7,7	47,02	78,22	20,17	7,31	21,95	31,75
Nombre de paysans	6		5		10		6		6	
Pluviométrie	744,7 mm 36 jours				458.8 mm 27 jrs		465,3 mm 29 jrs		505 mm 21 jrs	

Conclusion

De part son importance dans la région de Gaya (21% des superficie exploitées), l'association mil-sorgho est un système de culture qui permet aux paysans d'avoir deux productions de céréales mais aussi beaucoup de fourrage pour leurs animaux.

Elle a permis d'augmenter la production par unité de surface de 50 à 75% aussi bien en station qu'en milieu paysan.Dans tous les cas, la réponse des cultures aux engrais phophatés et azotés a été très significative. Une amélioration du système d'association mil/sorgho doit passer nécessairement par l'utilisation d'engrais minéraux et/ou organiques.

Une amélioration de la production de sorgho dans le système d'association est possible en augmentant le peuplement à l'hectare. En effet, on observe une augmentation de 40% de la production du sorgho sans apport d'engrais. Cette production peut être doublée avec un apport de 20Kg/ha de P_2O_5. Un apport en plus de 46 kg/ha N permet d'obtenir une production 2,5 fois plus élevée.

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Farmer Participatory Identification of Improved Millet Varieties for Western Niger

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Abstract

The transfer of technology approach which emphasized the introduction of high-yielding cultivars, successfully applied on irrigated lands during the green revolution era, needs to be modified in areas of harsh, rain-fed agriculture where the use of external input by farmers is still minimal. More importantly, farmer participatory research is required, in crop improvement and resource management research, to account for trade-offs that farmers would make.

A farmer participatory approach was used to screen and identify appropriate millet varieties for further on-farm testing in western Niger. Out of 13 advanced breeding lines and a local variety (cv Sadoré local) examined, ICMV IS 92222 and ICMV IS 94206 were identified by farmers as appropriate for western Niger. Good productive tillering, large grain size, stalk girth and earliness were the most preferred traits. Farmers are likely to reject millet varieties with the following traits: short or thin panicle; short or thin stalk; small grain size; and crop maturity period of more than 100-110 days. Farmers seemed willing to sacrifice some grain yield for other valuable traits. Therefore, it will be useful for scientists to use farmer participatory research to assess the relative value of a range of varietal traits.

Résumé

L'approche de transfert de technologies qui mettait l'accent sur l'introduction de cultivars de haut rendement et qui a été appliquée avec succès sur les terres irriguées durant la période de la révolution verte doit être modifiée dans les zones où l'agriculture pluviale se pratique dans des conditions difficiles et où l'utilisation d'intrants extérieurs par les paysans reste limitée. Chose encore plus importante, la participation paysanne à la recherche s'avère nécessaire pour l'amélioration des cultures et la gestion des ressources afin de justifier les choix que les paysans pourraient faire.

Une approche participative a été utilisée avec les paysans pour cribler et identifier des variétés de mil appropriées en vue d'une expérimentation supplémentaire en milieu paysan dans le Niger Occidental. Sur 13 lignées de sélection avancée et une variété locale (CV Sadoré local), ICMV IS 92222 et ICMV IS 94206 ont été identifiées par les paysans comme étant appropriées pour le Niger Occidental. Un bon tallage productif, une grosse taille de grain, une bonne circonférence de tige et la précocité étaient les traits préférés. Il y a beaucoup de chance que les paysans rejettent les variétés de mil ayant les traits suivants : panicule courte ou mince, tige courte ou mince, petite taille de graine et cycle de culture de 100-110 jours ou plus. Les paysans semblaient être disposés à sacrifier une partie du rendement en grain pour d'autres traits. Par conséquent, il sera utile pour les chercheurs d'utiliser la recherche participative en vue de déterminer la valeur relative d'une gamme beaucoup plus large de traits variétaux.

Introduction

Population growth, decreasing soil fertility, declining growing season lengths, and pest and disease pressures have created demands for technologies, institutions and policies needed to overcome constraints to food production. On the assumption that research centers have generated a large stock of appropriate technologies, international development agencies looked for ways to speed up the transfer of research results to farmers (Horton, 1992). The successful transfer of yield-increasing technologies during the green-revolution era provided support for the strategy whereby scientists developed new technologies on-station for extension agents to transfer to farmers. Farmers were seen as passive recipients of new technologies (Whyte, 1981). Farmer participation in the process was limited to the provision of land for on-farm trials (Tripp, 1982; Maurya *et al.*, 1988). As a result, systematic involvement of farmers in research has been weak in developing countries (Merrill-Sands and Collion 1993), particularly in the diagnosis of priorities and generation of technologies.

Explanations given for failure of direct technology transfer methods included: ignorance and conservatism of farmers, and low potential and riskiness of environment (Chamber, 1991). However, whilst internationally-available technologies can easily be transferred and adapted to well-endowed areas, the process of adaptation is more difficult where objectives and constraints of client farmers vary widely in the heterogeneous conditions of difficult areas (Farrington, 1988). The valuable insights of breeders and physiologists, on adaptability of cultivars to environments, need to be complemented with information about the relative values farmers attach to alternative plant and grain traits. This is because farmers are not passive recipients of recommended technologies, but active natural experts or researchers and developers in their own right (Haverkort *et al.*, 1991; Horton, 1992). There is, therefore, the need to shift from emphasizing the introduction of yield-increasing technologies to more effective farmer participation in determination of desired varietal traits.

The plethora of terms used to describe the research and extension paradigm focussed on the farmer include: farmer back-to-farmer (Rhoades and Booth, 1982); farmer-first-and-last (Chambers and Ghildyal, 1985); and farmer participatory research (Farrington and Martin, 1987). More and more researchers, as well as development workers, are now experimenting with approaches to technology development in which farmers play an active role (Haverkort *et al.*, 1991). Recent participatory research has involved farmers in the definition of research agenda, the conduct of research, the evaluation of research results, and the dissemination of findings (Farrington, 1988; Engel *et al.*, 1991). An important positive aspect of farmer participation in research is the provision of the "demand-pull" necessary to ensure accuracy of focus (Rhoades and Booth, 1982), through the effective tapping of the natural expertise of farmers and reflecting their preferences and objectives.

In plant breeding, the conventional approach for varietal selection involves multi-year, multilocational testing (principally for grain yield) of breeding lines developed at research stations. Varieties selected from this process are then released for multiplication and distribution. However, since breeders have a well-developed set of selection criteria which they implement, it is worth examining if other types of information need to be incorporated in breeders' criteria. To improve on the conventional approach to breeding, Maurya *et al.* (1988) suggested an alternative strategy which involved growing advanced lines and farmers' varieties under the same on-station conditions and matching traits. The implicit assumptions are that: the scientist uses the same selection criteria as the farmer of target area; and the local varieties embody all the good traits and exclude all undesirable traits. Neither assumption may necessarily hold.

This paper reports a similar experiment in which advanced breeding lines and a local variety (cv Sadoré local) were grown under the same on-station conditions. Unlike Maurya *et al.* (1988) sample farmers evaluated: plant traits in on-station plots; and grain traits of the same varieties in their homes. The objectives of the research were to use farmer participatory approach to identify: (i) advanced millet breeding lines that have traits desired by farmers of western Niger and, therefore, could be selected for further testing under farmer management conditions; and (ii) plant and grain traits preferred by farmers. The hypothesis is that farmers' choice of advanced lines will reflect trait preferences, including those that may not be embodied in existing locals.

Material and Methods

Thirteen new millet varieties and a local variety (Table 1) were planted in yield evaluation and demonstration trials conducted by the millet breeding program of the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) Sahelian Center at Sadoré, western Niger. The yield evaluation trial had a net plot size of 126 m^2 per replicate and four replicates per variety. The demonstration plots were unreplicated and slightly larger.

The plant and grain traits of all the 14 varieties were evaluated by a sample of 30 farmers, identified by their fellow farmers as very knowledgeable with respect to millet varietal traits. The sample farmers were selected in equal numbers from six villages in western Niger: Sadièze Koira and Samari in the Ouallam district; Berkiawel and Liboré in the Kollo district; and Dogol Kaina and Karé near Say. The selected villages span a north-south transect of western Niger. The assumption here is that farmer varietal preferences may be affected by differences in rainfall and season-length. Each group of five farmers consisted of three men and two women. This is an attempt to account for gender-based varietal trait preferences.

The identification of appropriate millet varieties and desired traits, by farmers, was conducted in two phases. First, farmers were invited, one zone after another, to spend half a day inspecting the plant traits of millet varieties in the yield evaluation and demonstration plots. The visits were conducted at 80 to 82 days after sowing (DAS) when farmers could get a good idea of the yield potential of each variety. Also, since the local millets were planted in the villages at about the same time as the on-station varieties, farmers could readily compare the maturity cycles of the new varieties to those of their own locals and the regional local used in the demonstration plot. Farmers were allowed to freely examine the different millet varieties at their own pace. On completion of the inspection of all the varieties, each farmer was invited to identify the preferred millet variety and identify desired traits of millet plants in general and the selected millet variety in particular. Information about undesirable traits, that would lead to rejection of new varieties, was also solicited.

Finally, farmers assessed the post-harvest processing and food quality traits of the same set of millet varieties in their homes. The women sample farmers and the wives of the male sample farmers were supplied two kilograms of each of the 14 varieties evaluated on-station. The grains were conditioned and processed into traditional food preparations by all the women together, prior to the assessment of the processing and food quality traits of the millet varieties.

Results

The highest-yielding variety was ICMV IS 89305, followed by the Sadoré local and ICMV IS 90309 (Table 1). However, on the basis of the observed plant traits, the varietal preferences indicated by the sample farmers showed that ICMV IS 92222 and ICMV IS 94206 were the most preferred varieties.

Table 1. Summary data on millet varieties grown at Sadoré in western Niger, 1994.

	Summary of attributes of the millet varieties					
Millet variety	Grain yield (kg ha^{-1})	Time to 50% bloom (days)	Plant height (cm)	Downy mildew incidence (%) ni	ai	Seed mass (g)
CIVT	0.94	67	234	1	16	11.3
GB 8735	--	54	160	4	4	12.2
ITMV 8001	--	72	251	1	1	11.3
SOSAT-C 88	--	64	203	0	0	11.8
ICMV IS 85333	0.56	71	233	1	8	11.5
ICMV IS 86330	--	64	232	4	4	11.8
ICMV IS 88212	1.00	69	245	0	4	11.3
ICMV IS 88217	1.10	69	226	0	4	11.5
ICMV IS 89305	1.54	75	254	1	12	11.0
ICMV IS 90309	1.21	70	235	0	0	10.8
ICMV IS 90311	0.86	70	230	0	0	10.0
ICMV IS 92222	1.06	67	251	00	0	11.5
ICMV IS 94206	0.90	71	267	0	4	11.0
Sadore Local	1.46	81	280	3	12	11.0

Source: Millet Breeding, Genetic Enhancement Division, ICRISAT Sahelian Center, Sadoré, Niger, 1994.

Notes: Fertilizer (kg ha^{-1}): 45N; $36P_2O_5$.

% Downy mildew: ai = artificial inoculation (in a separate downy mildew nursery trial; ni = natural infection that occurred in the yield evaluation trial).

Only grain yields obtained from replicated yield evaluation trial are reported.

— Unusually high grain yields recorded in unreplicated demonstration plots (for this variety as well as others that were in the yield evaluation trial) are not reported.

The major reasons indicated for the preference of ICMV IS 92222 are: productive tillering, stalk girth; earliness or short crop cycle; panicle girth; and large grain size (Table 2).

Table 2. Millet variety and trait preferences of sample farmers in Western Niger.

Preferred traits	Number of sample farmers indicating desired traits of preferred millet varieties[12]					
	ICMVIS 92222	ICMVIS 94206	ICMVIS 85333	ICMVIS 85321	ICM-VIS9240	Sadore Local
Good tillering	18	6	1	0	1	1
Earliness	13	7	0	1	0	0
Panicle lengt	1	5	0	0	0	0
Panicle girth (size)	13	6	0	1	1	1
Stalk length	0	5	0	0	0	1
Stalk girth	17	7	1	1	1	0
Large grain size	14	7	0	0	0	1
Grain yield	7	0	1	1	1	0
Ease of threshing	1	0	0	0	0	0

[12] Sample size is 30 farmers

The distribution of farmers who preferred ICMV IS 92222 was: six from the northernmost villages of Sadièze-Koira and Samari; five from the central zone villages of Berkiawel and Liboré; and seven from the southernmost villages of Dogol Kaina and Karé. Preference for ICMV IS 94206 was equally split between only the northernmost villages and the central villages.

In general, the farmers are likely to reject a millet variety that has the following plant traits: short panicle (73% of farmers); short stalk (70%); thin stalk (70%); small grain size (70%); crop cycle of 100-110 days or more (60%); and thin panicle (57%). The generally preferred plant traits are: good amount of productive tillering (90%); large grain size (70%); medium-sized girth of stalks (67%); and earliness (63%).

The evaluation of the post-harvest grain processing and food quality traits showed that roughly the same number of farmers expressed preference for ICMV IS 92222, ICMV IS 94206 and a local of western Niger (Table 3).

Table 3: Comparisons of farmer preferences for processing and food quality traits of preferred advanced millet varieties and Sadoré local.

Traits	Number of farmers expressing preference[13]		
	ICMV IS 92222	ICMV IS 94206	Sadoré local
1. Ease of:			
seed coat removal	17	21	23
grain grinding	20	20	22
2. Flour characteristics:			
yield/kg of	27	28	28
grain color	26	27	28
3. Porridge:			
color	25	26	28
taste	26	25	27
4. Tuwo (tô) characteristics:			
color	25	26	27
consistency	24	21	28
taste	24	23	28

[13] Total number of evaluating sample farmers is 28 (two original) sample members absent)

Discussion

Studies in Burkina Faso showed that farmers rejected new varieties due to technology-specific factors (Stoop *et al.*, 1982). The absence of traits preferred by farmers and/or the presence of unacceptable traits are technology-inherent qualities that constrain the adoption of new varieties by farmers.

Grain yield is the main selection criterion of crop improvement programs (Etasse, 1977). However, the third highest-yielding variety in the present study, ICMV IS 90309, was not selected by farmers. This was particularly because of its undesired panicle and grain characteristics, such as the shape and size of grains and panicle. In addition, the color and taste of its food preparations were unacceptable to many farmers. Therefore, selection of the variety on the basis of its exceptional yield would not necessarily match farmers' expectations. Similarly, ICMV IS 89305 (the highest yielder) was unacceptable to many farmers because of the shape of its grain. In addition, many farmers did not appreciate the amount of gloom that had to be removed from the grain. This simple farmer participatory screening or evaluation of millet varieties illustrates how inappropriate cultivars may end up being proposed, on the basis of yield, for on-farm trials only to be subsequently rejected by farmers.

The selection of ICMV IS 92222 as the most preferred millet variety by at least 50% of sample farmers from each of the three zones indicates that it has traits likely to be acceptable to farmers throughout western Niger. On the other hand, the recommendation domain for further on-farm test of ICMV IS 94206 may be limited to only the northernmost and central zones. Both varieties have days to bloom and plant heights that are much lower than those of Sadoré local (Table 1). Also, the seed mass of ICMV IS 92222 is much more than that of the local. Therefore, matching the traits of new advanced lines to existing locals may not necessarily capture all traits farmers are seeking.

The greater preference for good productive tillering, as compared to high grain yield, suggests that farmers in western Niger are more concerned about yield stability. The good tillering characteristic provides an insurance against damage or loss, resulting from pest damage or other external factors.

The preferences expressed by the sample farmers showed large range and diversity in combinations of desired traits. Only two, out of 30, farmers expressed identical combination of preferred traits. With large diversity of trait preferences, the appropriate "outcome" of a new technology cannot be encapsulated in a single technical criterion such as yield (Farrington, 1988). Participatory screening of cultivars can help identify a set of basic traits farmers want. This process will facilitate the adoption of new technology (Maurya *et al.*, 1988).

Since significant differences in performance are observed when millet cultivars are advanced to farmer-managed tests (Matlon 1987), it may be argued whether pre-screening by farmers from a target domain is needed prior to selection of varieties for on-farm testing. This is particularly because the logistics of transporting farmers to research stations/isolated sites would necessarily limit sample size, such that it might be questioned if results can be generalized. First, the differences are likely to be observed in only the grain and stover yields. Second, since the farmers were proposed by peers in the villages as knowledgeable about millet varietal traits, and hence opinion leaders, the preferences indicated could be expected to be fairly robust, despite the small sample size. Third, the involvement of farmers of target recommendation domains in pre-selection or evaluation of breeding lines offered opportunities to identify those which are likely to be accepted by farmers when proposed for testing under the farmers' condition. This strategy will minimize the proposition, for on-farm trials, of varieties selected by scientists on the basis of yield, or some other single criterion, which does not fully reflect the range of farmer priorities or objectives. Fourth, participatory preselection/screening of breeding lines, prior to proposing cultivars for on-farm testing, is also particularly relevant to millet or any other plant species which has a high degree of cross-pollination. This is because of the need to avoid introducing progressive "contamination" of local varieties with undesirable traits of new varieties which farmers of a recommendation domain will eventually reject.

Admittedly, farmer participation in selection of varieties for on-farm testing can easily be conducted for recommendation domains in which research stations are located. However, even in domains further from research stations, it should be possible to set up isolated areas where the new varieties can be grown, prior to farmer selection of appropriate varieties for further testing on farmers' fields.

Conclusion

International, regional, and national crop breeding network/programs face the challenging mission of providing appropriate improved cultivars for farmers in diverse physical and socio-economic domains. Cropping systems research could then select, from amongst many advanced lines produced from a regional perspective, the most appropriate millet varieties that can be further evaluated in specific farmer's production environment. To achieve the desired level of success and impact at the farm-level, breeding programs have to identify the right mix of preferred traits for defined recommendation domains.

Breeders have made tremendous progress in the search of cultivars adapted to target environment. However, varietal choices made by farmers suggest there could be desired trait trade-offs which may not be accounted for by the conventional selection criteria. Participatory diagnosis of preferred plant and grain traits during evaluation of breeding lines will therefore be needed. The resulting lessons could be beneficial to scientists and speed up the availability of desired improved varieties to farmers. There are also opportunities to map, using results from multilocational, participatory on-farm tests and geographic information system (GIS) technology, trait preferences as well as undesired traits at the regional scale.

An important drawback is the need for periodic farmer participatory screening of breeding lines to ascertain if trait trade-offs by farmers of a target domain have changed. This will take care of any dynamic changes in preferred traits and the need to replace varieties having less desirable traits with new ones.

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Evaluation de Deux Techniques d'Association de Cultures (Sorgho /Niébé; Maïs/Soja) en Milieu Paysan au Nord Togo

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Résumé

Les essais ont été conduits en milieu paysan dans la partie septentrionale du Togo, à savoir les régions de la Kara et des savanes. L'association sorgho/niébé avec ou sans traitement insecticide a été testée pendant trois campagnes agricoles (1990, 1991 et 1992) dans la région de la Kara. La variété améliorée vulgarisée de niébé 58-146 est associée à la variété locale de sorgho du paysan. Les résultats de ces trois campagnes montrent que les densités de 31.250 pieds/ha de niébé sous 62.500 pieds/ha de sorgho, semés à la même date n'entrainent aucun effet dépressif sur la céréale. Au niveau de la protection phytosanitaire, la meilleure rentabilité est obtenue par un traitement unique de l'insecticide administré au stade de l'initiation des boutons floraux. Le taux de rentabilité économique est de 302% par rapport au témoin.

L'association maïs/soja a été testée dans la région des savanes en 1994. La variété améliorée vulgarisée de maïs IKENNE 8149 SR et deux densités sont testées, à savoir:

- 1) 114.286 pieds/ha soja et 57.143 pieds/ha maïs
- 2) 71.000 pieds/ha soja et 40.800 pieds/ha maïs

Les premiers résultats montrent que la meilleure rentabilité est obtenue par l'association caractérisée par les densités de 114.286 pieds/ha maïs avec un ratio de rentabilité net de 124% par rapport à la culture pure de maïs. Au premier sondage, c'est donc cette technique qui semble le mieux intéresser le paysan.

Abstract

The trials are on-farm trials conducted in the Northern zone of Togo, namely Kara and savana regions. Sorghum/cowpea intercropping with or without insecticide treatment was tested during three cropping seasons in 1990, 1991 and 1992 in the Kara region. The released improved cowpea variety (58-146) was intercropped with the farmer is local sorghum variety. The results recorded during these three cropping seasons indicate that. 31,250 cowpea plants/ha under 62,500 sorghum plants/ha sown at the same date have no depressing effect on the cereal. Concerning plant protection, the highest profitability was obtained with the sole insecticide treatment at flower budding with an average of 302% net income increase compared to the check.

Maize/soybean intercropping was conducted in 1994 in the savana region. The improved soybean variety ISRA-44-A/73 was intercropped with the released improved

maize variety Ikenne 8149 SR. The two densities evaluated were:
114,286 soybean plants/ha and 57,143 maize plants/ha.
71,000 soybean plants/ha and 40,000 maize plants/ha.

The first findings showed that the highest profitability is obtained with intercropping at densities of 114,286 soybean plants/ha and 57,143 maize plants/ha with a net return of 124 % over maize sole cropping. From the first survey this latter technology appears to be of most interest to the farmer.

Introduction

Dans la partie septentrionale du Togo, le vivrier n'est pratiquement cultivé qu'en assosiations, sur l'ensemble des exploitations. Seules les cultures de rente (cotonniers, arachide etc...) sont parfois produites en monoculture. Généralement, quatre types d'associations à base de sorgho (sorgho/niébé, sorgho/mil, sorgho/arachide etc...) ou à base de maïs (maïs/niébé, maïs/arachide, maïs/sorgho/arachide etc...) sont pratiqués (Reneaud et Toky, 1986 et 1987). Les raisons avancées comme dans la plupart des pays de la zone semi-aride de l'Afrique de l'Ouest, comprennent notamment:

- la tradition,
- le besoin de minimiser l'impact du facteur le plus limitant,
- le besoin de sécurité alimentaire, et
- l'effet bénéfique des légumineuses sur d'autres cultures.

Ces raisons sont citées par Norman en 1977 et reprises en 1985 Par Fussell et Serafini. Abalu (1977) affirme en concluant que 'les paysans du Nord Nigéria utilisent l'association de cultures pour diversifier les activités et s'assurer ainsi contre les risques biologiques et économiques.'

Reneaud et Toky (1986 et 1987) notent que, les densités de semis utilisées par les paysans du Nord Togo restent cependant très faibles par rapport aux densités préconisées pour l'ensemble des plantes en associations. Par ailleurs, les variétés améliorées de niébé sont très peu utilisées dans les associations par le petit exploitant en raison de leur exigence en protection phytosanitaire. En effet, Traiter le Niébé exige la disponibilité en moyens financiers (crédits ou liquides) pour acheter les produits, les piles et louer l'appareil de pulvérisation; et trouver de l'argent en début de campagne reste toujours pour le paysan un problème relativement compliqué.

La première expérimentation (sorgho/niébé avec ou sans traitement insecticide), exécutée dans la région de la Kara, tente de démontrer la possibilité de rentabiliser le système à la fois par une densité optimale de niébé amélioré sous une densité normale de sorgho local et par un traitement minimum de la légumineuse.

La deuxième expérimentation (maïs/soja) exécutée dans la région des savanes, propose à l'appréciation et au choix du paysan, deux densités de soja en association avec le maïs. En effet, face à la dégradation progressive des sols occasionnée par une forte pression foncière, la vulgarisation est à la recherche d'une pratique culturale susceptible de restaurer la fertilité des sols de la région tout en assurant l'autosuffisance alimentaire de la population.

Matériel et Méthode

A) Expérimentation I

Les essais ont été conduits pendant trois années (1990, 1991 et 1992) dans la région de la Kara chez 40 paysans au total (9 paysans en 1990, 11 en 1991 et 20 en 1992). La variété améliorée vulgarisée de niébé (58-146), de cycle court, est utilisée en association avec le sorgho local du paysan. Les densités à l'hectare étaient de 31.250 pieds pour le niébé et de 62.500 pieds pour le sorgho. Le dispositif est celui de séries d'essais avec 3 répétitions par paysan. Les traitements sont au nombre de 5 :

- 3 parcelles associées avec une protection phytosanitaire (1 fois, 2 fois ou 3 fois suivant les parcelles).
- 1 Parcelle associée sans traitement insecticide (Témoin 1).
- 1 parcelle en monoculture de sorgho (même densité que dans l'association 62.500 pieds/ha) (Témoin 2).

La parcelle en monoculture de sorgho permet de vérifier l'absence d'effet dépressif de la légumineuse sur la céréale. A noter que dans la pratique traditionnelle, la céréale est considérée comme une culture principale dont la production ne doit pas baisser sous l'effet d'une culture secondaire associée.

Pour la protection phytosanitaire, le produit Arrivo D (13% Cyperméthrine + 100% Diméthoate) est utilisé à la dose de 2 litres/ha. Le premier traitement est effectué à 50% d'initiation de boutons floraux et les autres, tous les 10 jours pour les parcelles qui reçoivent plus d'un traitement.

Pour éviter le traitement indirect, sous l'effet du vent, des parcelles qui ne devaient pas l'être, les blocs sont séparés entre eux par une bande de 10 mètres; une allée de 2 mètres sépare les parcelles entre elles; les traitements phytosanitaires sont effectués les matins en l'absence du vent. Au moment du traitement, deux rideaux plastiques sont utilisés pour isoler la parcelle devant être traitée. A noter qu'une fumure de 100 Kg/ha de NPK (15.15.15) est utilisée.

L'interprétation statistique des résultats utilise les tests de Bartlett et de Duncan. L'approche économique calcule le taux de rentabilité marginale en tenant compte uniquement du coût variable de la protection phytosanitaire. C'est en effet, le facteur limitant le plus important dans l'adoption et l'utilisation des variétés améliorées. Les prix des denrées sont obtenus grâce àune mercuriale effectuée régulièrement sur les marchés de la place.

B) Expérimentation II

Les essais sont à leur première année d'exécution en 1994. Ils sont conduits dans la région des savanes, dans la Zone du Programme de Développement du Fonds Européen de Développement (FED), chez 5 paysans. La variété vulgarisée de maïs Ikenne 8149 SR est utilisée en association avec la variété améliorée de soja ISRA-44 A/73. Deux types d'association sont proposés en comparaison avec une monocultures de maïs.

1. Premier type d'association

- Maïs : 70 cm entre les lignes et 50 cm entre les poquets sur la ligne (2 plants par poquet) soit une densité à l'hectare de 57.143 plants.
- Soja : 2 poquets à 2 plants de soja après chaque poquet de maïs sur la même ligne semés à la même date, soit une densité à l'hectare de 114.286 plants.

2. Deuxième type d'association

Considérant le même écartement entre les lignes qu'en 1 (70 cm), seules deux lignes sur trois sont semées en maïs à 2 plants par poquet soit 40.800 plants à l'hectare et la 3ème ligne est semée en soja donnant ainsi une ligne de soja après deux lignes de maïs et une densité à l'hectare de 71.000 plants.

3. Maïs en monoculture (57.143 pieds/ha) (Témoin)

Le choix du paysan est orienté par la différence de production entre les parcelles associées et la parcelle en monoculture. Son intérêt réside dans la culture de la céréale et toute forme d'association qui conduirait à une diminution des rendements de la céréale ne serait pas adoptée volontiers par le paysan (Sawadogo et al., 1985). On évalue également la quantité de biomasse procurée par type d'association. A noter qu'une fertilisation de 100 Kg/ha de NPK (15.15.15) et 50 Kg/ha d'urée est appliquée. Le dispositif est une série d'essais sans répétition, 1 bloc par paysan. L'analyse statistique utilise le test de Newman Keul au seuil 5%. L'approche économique tente uniquement de dégager les rapports nets de chaque type d'association par rapport à la monoculture. Les prix du maïs et du soja n'étant pas constants au cours de l'année, une moyenne des prix de 1994 est obtenue grâce à une mercuriale effectuée régulièrement au marché de Dapaong.

Pour les deux expérimentations, la réalisation est assurée grâce à une collaboration étroite entre la recherche et les structures de vulgarisation et de développement rural, notamment les chefs de secteurs et sous-secteurs agricoles, et les encadreurs ruraux de base. La recherche fournit le protocole expérimental et les intrants. L'encadreur choisit le paysan dans la mise en place de l'essai, note les observations, enregistre les réactions du paysan et participe à la récolte. Le chercheur apporte son appui technique à l'encadreur par des visites périodiques des parcelles. Il explique le protocole, encourage le dialogue entre la recherche, la vulgarisation et le paysan. Il assiste à la récolte, effectue les pesées, analyse les résultats et rédige le rapport. Le paysan assure toutes les activités culturales (préparation du sol, semis, sarclage etc...). Le produit de la récolte lui revient intégralement.

Résultats et Discussions

A) Expérimentation I

Sur un total de 40 essais implantés durant les 3 années, 15 sont éliminés pour des raisons diverses : (mauvaise implantation, dégâts d'animaux, erreur de traitement ou de récolte etc...). 25 essais (6 en 1990, 9 en 1991 et 10 en 1992) considérés comme fiables et exploitables sont groupés et analysés.

Sur le plan Agronomique

Cas du sorgho: On note un bon comportement végétatif de la céréale pendant les trois années consécutives (Tableau 1). La production est similaire d'une année à l'autre avec un rendement moyen à l'ha de 972 Kg. L'interprétation statistique ne montre aucune différence significative entre les traitements mettant en évidence l'absence d'effet dépressif de la légumineuse sur la céréale dont la production moyenne est similaire en association et en monoculture. Ceci, répond bien aux exigences du paysan pour qui la céréale est la culture principale. Sa production ne doit pas être affectée par la légumineuse considérée comme une culture secondaire. Les résultats sont fiables et homogènes durant les trois années avec des coefficients de variation acceptables (13,39% en 1990, 18,41% en 1990, 18,41% en 1991 et 10,8% en 1992).

Tableau 1. Rendement kg/ha et classement - récapitulatif 1990-1991-1992.

N°	Traitements	Rendement kg/ha et classement							
		1990		1991		1992		Moyenne	
		Sorgho	Niébé	Sorgho	Niébé	Sorgho	Niébé	Sorgho	Niébé
1	Sorgho/Niébé + 3 traitements insecticide	1035	761 a	908	458 a	940	232 a	961	484
2	Sorgho/Niébé + 2 traitements insecticide	1014	452 b	1027	305 b	934	137 b	992	298
3	Sorgho/Niébé + 1 traitements insecticide	1079	314 c	1017	239 c	869	87 c	988	213
4	Sorgho/Niébé + 0 traitements insecticide	963	156 d	921	55 d	893	16 d	926	76
5	Sorgho en monoculture	1068		948		965		994	
	Moyenne	1032	421	964	264	920	118	972	268
	CV %	13.39	18.78	18.41	16.54	10.8	19.7		

Cas du Niébé: Les résultats mettent en évidence la fragilité et la sensibilité de la légumineuse face aux aléas environnementaux. On note essentiellement une instabilité de production d'une année à l'autre. La première année d'expérimentation a été particulièrement favorable à la culture du niébé avec une moyenne de production de 421 Kg/ha contre 264 Kg et 118 Kg seulement en 1991 et 1992, en raison des précipitations plus abondantes et un développement important du parasitisme. Les résultats sont cependant encourageants avec une production d'une plus-value substantielle de l'ordre de 268 Kg/ha en moyenne susceptible d'intéresser le paysan. En effet, l'absence d'effet dépressif de la légumineuse sur la céréale lui permet une augmentation de la production à l'unité de surface. L'expérimentation met en évidence l'efficacité de la protection phytosanitaire des niébés avec une augmentation de production en rapport avec le nombre de traitements insecticides. A noter qu'un seul traitement appliqué à

50% d'initiation de bouton floraux permet de doubler la production_par rapport ou sans traitement.

Statistiquement, les résultats sont assez fiables et homogènes avec des C.V. de 18,78%, 16,54% et 19,7% respectivement en 1990, 1991, 1992.

Sur le plan Economique

L'approche économique tente de calculer le taux de rentabilité marginale des traitements insecticides par rapport au témoin (sans traitement). La production de la céréale étant statistiquement identique sur toutes les parcelles et durant les 3 années, une moyenne de 972 Kg/ha est utilisée dans le calcul (Tableau 2). Les prix des denrées et des intrants sont une moyenne de ceux des années 1990, 1991 et 1992 (Période d'exécution de l'expérimentation).

Tableau 2: Approche économique - Taux de rentabilité marginale: Synthèse 90-91-92.

Options	0 traitement	1 traitement	2 traitements	3 traitements
Sorgho grain rendement kg/ha	972	972	972	972
Niébé grain rendement kg/ha	76	213	298	484
Augmentation rendement niébé kg/ha		137	222	408
Revenu brut sorgho f. CFA	77663	77663	77663	77663
Revenu brut niébé f. CFA	9348	26199	36654	59532
Revenu total brut f. CFA	87011	103862	114317	137195
Coûts fixés (engrais) f. CFA	6500	6500	6500	6500
Coûts variables (insecticide) f. CFA (c)		4164	8328	12492
Bénéfices nets f. CFA	80511	93198	93489	118203
Augmentation bénéfices nets f. CFA (v)		12687	18978	37692
Taux de rentabilité marginal (v/c x 100)		305%	228%	302%

Prix moyens 1990 à 1992:
en francs CFA)

Niébé: 123 frs/kg
Sorgho: 79,9 frs/kg
Engrais: 65 frs/kg
Insecticide: 1600 frs/l
Piles: 600 frs/passage
Pulvérisateur: 364 frs/passage

Si l'on considère que la valeur du rapport V/C (V = augmentation des bénéfices nets due à l'investissement dans la protection phytosanitaire et C = Coûts variables de cet investissement) doit être au moins égale à 2 pour que l'opération soit considérée comme payante, le tableau 2 met en évidence la nette rentabilité des insecticides sur le niébé avec des ratios de 3,05; 2,28; et 3,02 pour respectivement 1, 2 et 3 traitements, soit des valeurs théoriquement attractives.

Si la technique se montre payante, on note que la meilleure rentabilité n'est cependant obtenue qu'avec le traitement unique de l'insecticide effectué à 50% d'initiation des boutons floraux. Traitement d'autant plus rentable qu'il économise temps, fatigue et argent par rapport aux traitements double (2) et triple (3).

B) Expérimentation II

Les essais prévus sont réalisés. L'interprétation statistique du regroupement montre une bonne homogénéité des résultats. Ces résultats confirment en première année, ceux observés en milieu contrôlé. On note :

Sur le plan Agronomique

Cas du maïs : On note pas de différence significative entre les traitements mettant en évidence l'absence d'effet dépressif de la légumineuse sur la céréale et le bon comportement de la densité normale de 57.143 pieds/ha (Tableau 3). Les rendements étaient assez élevés avec une moyenne à l'hectare de 19 quintaux.

Tableau 3. Maïs/Soja - production moyenne.

N°	Traitements	Rendements (kg/ha) Maïs	Maïs
1	Maïs associé 57.143 p/ha	1875	677
	Soja associé 114.286 p/ha		
2			
	Maïs associé 40.800 p/ha	1578	671
3	Soja associé 71.000 p/ha		
	Maïs pur	2330	
	Moyenne	1928	674
	CV %	21,7	12,1

Cas du soja : Les différences entre traitements n'étaient pas significatives. par conséquent les deux densités semblent avoir des comportements identiques. On note un apport substantiel de matière sèche, susceptible de restaurer au sol après enfouissement une matière organique importante. Cependant, aucune information n'a pu être obtenue sur la quantité réelle de cette matière sèche.

Sur le plan économique

- En général, les rapports de rentabilité nette étaient plus élevés dans les parcelles associées par rapport aux parcelles produites en monoculture. C'est ainsi qu'on note une meilleure rentabilité de la première association maïs/soja (57.143/114.286 pieds/ha) avec un rapport de 124% par rapport à la monoculture de maïs (Tableau 4). Par ailleurs, comparée aux associations mil/niébé et sorgho/niébé, l'association maïs/soja est, sans nul doute, plus payante pour le paysan pour deux raisons essentielles:

1. Une productivité supérieure des deux plantes maïs et soja.
2. L'absence de protection phytosanitaire, d'où, une économie en terre et des avantages pécuniaires très élevés.

Tableau 4. Association Maïs/Soja - Approche économique

Traitements	Rendement kg/ha	Engrais CFA/ha	Equivalent vivrier kg	Rapports Nets		
				kg/ha	frs. CFA	%
Maïs associé	1875	15 000	214	1661	183.970	
Soja associé	677			677		124
Maïs associé	1578	15 000	214	1364	162.580	
Soja associé	671			671		109
Maïs pur	2330	15 000	214	2116	148.120	100

Les différent prix: (en frs CFA)
Engrais : 100 frs/kg
Maïs : 70 frs/kg
Soja : 100 frs/kg.

La teneur élevée en protéines (38%) et en glucides (18%) de la graine de soja fait de cette légumineuse un aliment protidique et énergétique de choix (Mémento de l'Agronome, 4ème Edition, 1991, PP, 926 - 927). Il reste cependant peu utilisé à cause du manque de procedé de transformation répondant au goût des paysans.

Conclusions et Recommandations

A) Expérimentation I

Après trois années d'expérimentation les résultats mettent en évidence, la rentabilité de l´association sorgho/niébé par l'absence de concurrence de la légumineuse sur la céréale aux densités prescrites (62.500 pieds sorgho/31.250 pieds niébé), avec une augmentation significative de la production à l'unité de surface par rapport à une monoculture de sorgho.

- La rentabilité de la protection phytosanitaire du niébé avec des rapports V/C supérieurs à 2.

- La meilleure rentabilité du traitement unique d'insecticide par rapport aux traitements double (2) et triple (3), étant donné que celui-ci économise temps, fatigue et argent.

Compte tenu de ces résultats, le développement est en mesure d'apporter aux petits exploitants une amélioration sensible de la rentabilité de l'association phytosanitaire économique, exécutée en une seule fois à un stade végétatif précis de la plante : 50% initiation de boutons floraux.

Il apparait donc indispensable au développement de bien conseiller le paysannat, le respect du suivi du paquet technique propre à l'association étant la condition 'sine qua non' de rentabilité de la technique.

B) Experimentation II

Ces premiers résultats sont encourageants; notamment l'absence d'effet dépressif de la légumineuse sur la céréale, mettant en évidence une augmentation de la production à l'unité de surface. A noter également que le soja, par son système racinaire et son feuillage, peut efficacement contribuer à l'amélioration de la fertilité des sols. Au sondage, les paysans ont tendance à préférer la première association 57.143 pieds/ha de maïs et 114.286 pieds/ha de soja.

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A Coordinated Technology Generation and Delivery System for Enhanced Sorghum Production and Utilization in West and Central Africa

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Abstract

The combined efforts of the National Agricultural Research Systems (NARS), regional and international agricultural research systems have generated a number of crop varieties and agronomic techniques in West and Central Africa. The prospects of substantially improving the welfare of producers and consumers through sorghum research have improved in the last decade. At the same time, progress is being made in the policy arena to improve the conditions and incentives for farmers. The NARS and international research organizations are restructuring the technology development and transfer systems to ensure widespread adoption. This paper reviews the efforts being made by the NARS, IARCs and research directors to coordinate sorghum technology development and transfer in West and Central Africa.

Résumé

Les efforts conjoints des Systèmes Nationaux de Recherche Agricole (SNRA) et des systèmes régionaux et internationaux de recherche agricole ont permis de mettre au point un certain nombre de variétés culturales et de techniques agronomiques dans la région. Au cours de la dernière décennie, les perspectives se sont améliorées en ce qui concerne l'impact de la recherche sur le sorgho et le mil au niveau des populations. En même temps des progrès sont enregistrés sur le plan politique pour l'amélioration des conditions et des incitations au niveau paysan. Les SNRA et les organisations internationales de recherche sont en train de restructurer les systèmes de développement et de transfert de technologies en vue d'assurer une adoption de ces technologies sur une grande échelle. La présente communication passe en revue les efforts déployés par les SNRA, les CIRA et les directeurs de recherche pour coordonner la mise au point et le transfert de technologies en Afrique Occidentale.

Introduction

Sorghum, millet, maize and rice constitute the principal staple cereals for roughly 155 million people living in West Africa. While sorghum and millet are mostly produced and consumed in the predominantly arid/semi-arid parts, maize is better adapted to, and consumed mostly in, the humid/sub-humid parts. Rice is consumed widely especially in the urban centres of the region. Sorghum and millet are considered as "food security" crops for the inhabitants of the semi-arid areas who are among the poorest groups of the region. These people depend on sorghum and millet for their survival as no other cereal crops adapt better to the marginal environment. Their low incomes do not permit direct access to food and food aid cannot be relied upon to support the population on a regular basis. As food security crops, they are expected to provide the population with timely, reliable and nutritionally adequate supply of food on a regular basis. However, because of climatic variations, technology development and transfer constraints, as well as government policy, the supply of sorghum and millet has been irregular over time and space in the region.

In an effort to reduce the gap between the fast population growth (about 2.7% per annum) and low food supply, food crop research was initiated in the early sixties. In francophone West African countries, this was in the form of bilateral programmes with the Institut de Recherche Agronomiques Tropicales (IRAT). In the early seventies, the international agricultural research centres (IARCs), notably ICRISAT and IITA began operations in West Africa. Unfortunately, the food crisis worsened in the 1970s when widespread drought and civil disruption led to severe famine in many parts of Africa. As a direct response, the African Heads of State created the Semi-Arid Food Grain Research and Development (SAFGRAD) project in 1977 to provide a African umbrella for working across linguistic and political boundaries and for assisting and strengthening NARS through training , information exchange, testing and adaptation of different crop varieties and other agricultural technologies developed by IARCs (notably ICRISAT and IITA) and other NARS. The rest of the paper reviews the progress made in sorghum technology development and transfer in the region, and suggests some modifications necessary to promote greater adoption of these technologies.

Sorghum Technology Development and Transfer Systems in West and Central Africa

The combined efforts of research by the National Agricultural Research Systems (NARS) and the different regional and international institutions have led to the development of a large number of improved foodcrop varieties of different maturities and characteristics suitable for the largely diversified West African environment (Table 1). Most of the materials have been tested across locations through different mechanisms including regional trials of the sorghum research network (Table 2). The yields (mostly on-farm data) are generally high, and average about four times more than the average yields of the local varieties. Most of them are already released and in farmers' fields while the others are being further tested on-station prior to release.

The successes of the Asian Green Revolution have influenced the disproportionate emphasis on varietal development vis-a-vis resource management techniques in foodcrop research in West Africa. In particular, agronomic research, which has been responsible for over 60% of sorghum yield gains in the United States (Miller and Kedebe, 1984) has not received much attention in West Africa. Much of the agronomic research in sorghum involved the development of technologies aimed at increasing productivity (fertilization, intercropping, etc.). Technological packages using various combinations of variety, fertilizer, ploughing and tied ridges developed by the ICRISAT/Burkina

Faso programme are known (based on results from on-station and on-farm) to yield between 1000 and 3000 kg ha^{-1} (Matlon, 1990). The ICRISAT/Mali bilateral programme has also developed sorghum-cowpea, millet-cowpea and maize-millet intercropping systems that result in yield increases of between 30% and 40% over corresponding monocropping systems (Schilling *et al.*, 1989). Other resource management-type techniques include a variety of run-off management systems that focus on erosion control and/or water harvesting. In Burkina Faso, Hulugalle *et al.* (1990), showed that a combination of permeable rock bunds and tied ridges increased sorghum and millet yields by roughly 55%.

Table 1 . Changing patterns of foodgrain production in West Africa 1961-65 to 1987-91[1]

West Africa	Area (mil. ha)			Production (mil. Mt)			Yield (kg/ha)		
	61-65	87-91	change	61-65	87-91	change	61-65	87-91	change
Sorghum	8.7	9.4	0.7	6.3	8.2	1.9	724	872	148
Millet	9.6	11.8	2.3	5.4	8.7	3.3	562	737	175
Maize	3.2	4.3	1.1	2.4	4.9	2.5	750	1140	390
Rice	1.5	3.5	1.9	1.5	5.3	3.8	1000	1514	514
Total	23	29	6	15.6	27.1	11.5			
Arid & Semi-arid Countrie									
Sorghum	2.8	4.2	1.4	1.6	2.5	0.9	571	595	24
Millet	4.6	7.3	2.7	2.4	3.7	1.3	522	507	-15
Maize	0.32	0.54	0.22	0.24	0.6	0.36	750	1111	361
Rice	0.34	0.39	0.05	0.4	0.7	0.3	1176	1794	618
Total	8.1	12.4	4.3	4.7	7.5	2.8			
Humid & Sub-humid Countries									
Sorghum	5.9	5.3	-0.6	4.7	5.7	1.0	796	1075	279
Millet	4.9	4.5	-0.4	3.00	4.9	1.9	612	1088	476
Maize	2.9	3.79	0.89	2.2	4.3	2.1	758	1134	376
Rice	1.1	3.07	1.97	1.16	4.5	3.3	1054	1465	411
Total	11.06	16.6	5.6	11.06	19.4	8.3			

Source: Computed from FAO Agrostat Database, 1994.

[1] Data for "West Africa" in column 1 includes CAR and Cameroon. Data presented for the "humid/sub-humid" countries includes Nigeria. Without Nigeria, harvested area, production and yields data are 30 % lower than those reported for sorghum and millet.

Table 2. Characteristics of selected sorghum varieties tested in Regional Trials by the West and Central Africa Sorghum Research Network (WCASRN), 1986 to 1992[*2]

Variety	Maturity Cycle	Average yield (t/ha)	Origin	Country of Current Use	current status
CE 180-83	Early	2.38	Senegal	Senegal Togo	Pre-release On-station
CE 196-7-2-1	Early	2.53	Senegal	Senegal	Farmer's fields
Nagawhite	Early	3.53	Ghana	Mauritania	On-station
S-35	Early	3.23	Nigeria ICRISAT/India	Togo Chad Cameroon	On-station Farmer's fields Farmer's fields
ICSV 111 IN	Early	3.27	ICRISAT/India	Senegal Togo Ghana Nigeria Benin	On-station On-station Pre-release Farmer's fields Pre-release
ICSV 1079 BF	Early	2.74	ICRISAT/ Burkina Faso	Mali Togo	Farmer's fields On-station
ICSV 1078 BF	Early	3.66	ICRISAT/ Burkina Faso	Mali / Togo	On-station
ICSV 1083 BF	Early	2.5	ICRISAT/ Burkina Faso	Togo	Farmer's fields
Malisor 84-1	Medium	3.08	Mali	Guinea Cote d'Ivoire Togo	On-station Pre-release On-station
BF 83-3/48-2-2	Medium	2.10	Burkina Faso	Senegal	Farmer's fields
F2 - 20	Medium	2.34	Senegal	Senegal	Farmer's fields
CS-96	Medium	2.32	Cameroon	Togo	On-station
Sepon 82	Medium	1.96	Niger / ICRISAT Burkina Faso	Senegal / Togo	On-station
S-129	Medium	2.33	Cote d'Ivoire	Ghana	On-station
ICSV 1171 BF	Medium	2.37	ICRISAT/ Burkina Faso	Senegal	On-station
ICSV 1089 BF	Medium	3.01	ICRISAT/ Burkina Faso	Senegal Mali Togo	Farmer's fields On-station On-station
ICSV 1063 BF	Medium	3.34	ICRISAT/ Burkina Faso	Mali Togo	Pre-release On-station

Source: WCASRN (1992) Synthesis of primary data, Vol 2: Tables and Figures

Mean yields from several research locations in West and Central Africa between 1986 and 1992.

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* More recent early maturing varieties and hybrids of ICRISAT/Nigeria origin currently in pre-release stages in Nigeria are ICSV 400, ICSH 89002 and ICSH 89009.

On the demand side, sorghum technology has focused on processing, food technology and storage techniques that enhance sorghum demand. Examples are from Nigeria where the local sorghum variety, Farafara and improved variety, SK 5912 supplied 50% of the sorghum-wheat composite flour from which acceptable bread and confectionery were made (Olugbemi, 1992). In Mali, sorghum and millet are being combined with cowpea for use as weaning foods (Haidara, 1992). Research has also shown the technical feasibility of using sorghum in the production of clear beer. In Nigeria roughly 205000 tons or 2.5% of total production is used for industrial production of clear beer (Baidu-Forson and Ajayi, 1995).

The recent evaluation of the SAFGRAD commodity networks in West and Central Africa showed that substantial impacts from maize and cowpea research have been made (Sanders *et al.*, 1994). Similar progress has also been made in sorghum and millet research in recent years. Schilling *et al.*(1989) estimated that, in Mali, less than 1% of the total sorghum area in the Mopti region was grown to improved varieties. A year later, Matlon (1990) estimated that only about 5% of the total sorghum and millet area in the West African Semi-Arid Tropics (WASAT) was cropped to improved varieties. Today, however, there is a move toward a wider adoption of improved varieties of sorghum in the region. In northern Cameroon, for example, after seven years of diffusion of the sorghum variety S-35, the estimated benefits were about US$831,000 (Sanders *et al.*, 1994). The same variety has been successfully adopted in neighbouring Chad where it is said to cover between 150,000 and 200,000 hectares (29% to 39% of total sorghum area). This new development is needed and should be encouraged and promoted through further improvement in the technology development and transfer system to ensure greater adoption of sorghum technologies.

Prospects for Greater Adoption of Sorghum Technologies

The reasons for non-adoption of sorghum technologies on a large scale in the region vary. They include: (i) inadequacies in the technology development and transfer system; (ii) lack of economic incentives for adopting new technologies; and (iii) poor coordination of research efforts in the region.

Inadequacies in sorghum technology development and transfer systems

Many sorghum technologies were not adopted because they did not address key concerns of farmers. This was essentially the result of the inadequate technology development and transfer systems that have dominated sorghum research in West Africa since the early sixties. Example of these include the transfer of technology (TOT) model, and the farming systems research (FSR) model.

In the TOT model, farmers were treated as recipients of technology, end-users, clients or customers and the research agenda was usually set by scientists on the basis of their perceptions of farmer's circumstances. This "top-down" approach has been the dominant model in sorghum research in West Africa. Its major weakness is the lack of linkage between the researcher, extension personnel and farmers. Its basic assumptions are inspired by the Asian Green Revolution, some of which are not relevant to the West African conditions. For example, the agricultural systems of West Africa are more fragmented and more diversified than those of Asia, hence any technology development and transfer process must take into account the specificity of the farmers' environment.

In West Africa, scientists had in the past emphasized high and stable yields and paid little attention to grain quality and other issues of consumer preference in their breeding objectives. As a result, improved cultivars and technologies were developed without adequate farmer feedback from the end-users. Although high and stable yields are important and highly desirable, the grain quality suitable for preparation of specific traditional foods are of equal importance to farmers. TOT also assumes that on-shelf technologies from elsewhere could be transferred to the WASAT to improve productivity. However, experience in the early years of varietal research in West and Central Africa showed that the direct transfer of improved genetic materials was difficult due to differences in their adaptation to soil, pests and diseases.

The FSR model introduced components of socio-cultural, political, economic and gender issues into the technology development and transfer process. Often, multidisciplinary teams of researchers and extension personnel diagnose problems, develop technologies to address them and end with evaluation of these technologies. Farmers are consulted but do not play any significant role. This approach is similar to the TOT approach in the sense of delivering "finished products" to farmers who are often peripheral to the problem identification and technology development.

More recent approaches to sorghum research involve the active participation of farmers in the technology development process. While the approach may be known variously as farmer participatory research, farmer first, farmer-back-to-farmer, they all involve farmer participation in setting research agendas, in carrying out experiments and trials, and in the technology dissemination process. Farmers' fields and conditions are the primary locus of research. In this approach, genetic materials, cultural practices and other technologies are developed in conjunction with the farmers and are made available in such a way that farmers can select the materials that best suit their individual circumstances (Chambers, 1989). This approach is now being emphasized in recent times in both the NARS and IARCs, to ensure that farmers' and scientists' objectives are harmonized in the technology development and transfer process.

Lack of incentives

Uneconomical technologies, price fluctuations, risky semi-arid environment, government preferential pricing, credit and marketing policies, and lack of storage and mechanized processing facilities and transport, all discourage farmers from investing in new technologies. Often the improved varieties and agronomic techniques require purchased inputs or major modifications of established cropping systems. They sometimes require significant amounts of additional labour, particularly during the peak periods of the cropping season. The ineffective links between product markets and input supplies (fertilizer, seed, agro-chemicals, equipment) and credit have limited farmers' incentives to adopt improved technology. Price fluctuations also discourage farmers from investing in new technologies. In poor rainfall years, prices of the basic food crops become very high while in good rainfall years they become very low. Prices also vary substantially across limited distances due to lack of market information, transport and infra structural constraints. They vary similarly across time because of the limited capacity to hold grain stocks.

Seed availability has also been a major constraint to adoption of sorghum varieties in the region. In the few successful cases in which widespread adoption of sorghum varieties have occurred (e.g., S-35 in Cameroon and Chad), there has been a strong seed multiplication and distribution support. Processing technologies to transform sorghum into finished, or readily usable forms for human consumption are limited. This has affected the competitiveness of its consumption relative to maize and rice in the urban areas. Marketing opportunities for sorghum in the form of feedstock, beverage or industrial utilization are not well developed in West Africa. Exploiting the opportunities for alternative uses of sorghum will enhance the adoption of new sorghum technologies.

Poor coordination of research efforts in the region

The NARS, IARCs and NGOs play a major role in sorghum technology development and transfer in the region. The research efforts and linkages between the various institutions have not been properly coordinated. This has led to duplication, inefficient use of resources and long time spans between constraint identification and the development and transfer of technologies to overcome them. A major attempt at regionalisation of sorghum research through collaborative research began in 1984 with the creation of the West and Central Africa Sorghum Research Network (WCASRN). The objectives were to address constraints of regional significance and the establishment of links with national, regional and international institutes to serve the region effectively. The recent evaluation of the regional sorghum research network was positive. It showed that the network successfully shared technology between countries and that the NARS have taken on an increasing responsibility for the networks (Sanders *et al.*, 1994). The evaluation recommended more effective links between the IARCs and their collaborators to obtain the critical mass and the complementarity required to address constraints to sorghum production in the region.

Conclusion

Productivity gains in food crop production, through genetic improvement alone, are particularly difficult to achieve in the semi-arid regions of West and Central Africa. Yet prospects for achieving people-level impacts from investments in agricultural technology development and transfer have improved over the last decade. The amount of technology available to influence productivity gains has increased and those in the pipeline suggest that future prospects are good for further productivity gains. At the same time, progress is being made in the policy environment influencing the operations of input and output markets that have significant impacts on the conditions and incentives of farmers. The NARS and their IARC counterparts are restructuring their research, development and transfer mechanisms to harness synergism and to foster complementarity. The prospects of further productivity gains in sorghum research are conditioned by the availability of finances and better coordination of research in the region. Further investments in sorghum technology development and transfer are essential, and must be coordinated between researchers and research administrators in order to achieve farm-level impacts that are sustainable.

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Technology Options and Adoption: The Case of Two Sorghum Varieties in Northern Guinea Savanna of Nigeria

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Abstract

Sorghum is the most important food grain crop among the people of northern Guinea savanna of Nigeria. The yields from the local varieties are, however, very low. To improve the productivity of the crop, the Institute for Agricultural Research (IAR), Samaru released two varieties: SAMSORG-20 in 1977 and SAMSORG-14 in 1982. The two varieties were taken on-farm in 1984/85 cropping season for on-farm adaptive research (OFAR) trial with the objective that the farmers would adopt them at the end of the trial. Before the end of the fourth year of the trial, it had become clear that SAMSORG-14 was highly acceptable to the farmers, as not only the participating farmers, but also some neighbouring farmers had adopted it. This paper examines the qualities of the variety that made its widespread adoption possible. It also reports results of a follow up survey conducted in 1994 to determine the extent of its adoption and popularity. It is concluded that good technologies sell themselves and that OFAR is a good avenue for propagating farm technologies to peasant farmers.

Résumé

Le sorgho était la culture vivrière la plus importante chez les populations de la Savane Nord-guinéenne du Nigéria jusqu'à ce que le maïs prenne récemment de l'importance aussi. Les rendements des variétés locales étaient cependant très faibles. Pour améliorer la productivité de la culture, l'Institut de Recherche Agricole (IAR) de Samaru a vulgarisé deux variétés : l'une, SAMSORG-20 en 1977 et l'autre SAMSORG-14 en 1983. Les deux variétés ont été expérimentées en milieu paysan durant la campagne agricole 1984/85 dans un essai de Recherche Adaptative en Milieu Paysan (OFAR), avec l'espoir que les paysans les adopteraient à la fin de l'essai. Avant la fin de la quatrième année, il est apparu clairement que SAMSORG-14 était la variété choisie par les paysans, car non seulement les paysans participants mais aussi quelques paysans voisins avaient adopté la variété. Cette communication examine les qualités de la variété qui ont permis sa large adoption et présente les résultats d'une enquête de suivi menée en 1994 pour se rendre compte de son degré d'adoption et de popularité à l'heure actuelle. Elle conclut que la technologie se vend d'elle-même et que la Recherche en Milieu Paysan est un bon moyen de vendre les technologies agricoles auprès des paysans.

Introduction

Sorghum was the most important cereal crop in the northern Guinea savanna (NGS) of Nigeria in the 1970s, in terms of per capita consumption and hectarage cultivated (Norman *et al.,* 1976). The other important cereal crops were millet and maize which ranked second and third, respectively. Even in the recent times, sorghum is still the most important food cereal crop but maize now occupies the second most important position. However, in terms of income generation from production, maize is the most important cereal crop in the zone (Ahmed, 1995).

In the 1970s, the varieties of sorghum cultivated in these areas were the local types which have low yields. The need to improve their productivity led to the development of higher yielding varieties by the Institute for Agricultural Research (IAR), Samaru (Zaria). Two of these varieties: SAMSORG-20 (L.187) and SAMSORG-14 (KSV8) were released in 1977 and 1982, respectively. SAMSORG-20, which is a long maturity variety, was taken for on-farm adaptive research (OFAR) in 1982/83 cropping season. The rainfall that year, unfortunately, started very late and also ceased early so that the total rainfall was only 608 mm which was about 21% lower than that for 1981 (IAR, 1984). The crop performed poorly on the farmers' fields which made them request for a variety which matures earlier and which may do well in years of low amounts of rainfall. SAMSORG-14 which is of medium term maturity, and which was earlier developed for the Sudan savanna, met this requirement and was taken for an OFAR in the northern Guinea savanna in 1984/85. The SAMSORG-14 trial which was done using one farmer performed extremely well and the number of subsequent participants was increased. From the 1985/86 season, the two varieties were tested by each of the participating farmers.

Features of SAMSORG-20 and SAMSORG-14 Varieties

The two sorghum varieties have certain characteristics which are distinct from one another and which have different appeals to the farmers. These characteristics are shown in Table 1.

Table 1. Characteristics of SAMSORG-20 and SAMSORG-14 when grown in the northern Guinea savanna, Nigeria.

Year	Average yield (kg/ha)	
	SAMSORG-20	SAMSORG-14
1982/83	1560	NA
1983/84	1491	NA
1984/85	1121	NA
1985/86	1224	NA
1986/87	1221	1301
1987/88	1822	2034
1988/89	NA	2257

Source: IAR (1986): Cropping Scheme Report.

On the basis of maturity, SAMSORG-20 takes a longer time to mature compared to SAMSORG-14. Consequently, the duration and the total amount of rainfall affect the two varieties differently. The heights of the varieties were quite different. Thus SAMSORG-14 is three times taller than SAMSORG-20. This has implications for the farmers since sorghum stalk is used for feeding animals, for fencing and roofing, and as fuel for cooking. The colour of the two varieties were also different. SAMSORG-14 is white while SAMSORG-20 is yellow. The difference in colour has implications for their use as food because the white colour is preferred to the yellow colour. However, the average yields were significantly different, with SAMSORG-20 yielding twice as much as SAMSORG-14. The implication of this difference is that farmers would prefer the higher yielding variety to the lower yielding one. Each of these features were demonstrated to the farmers in the course of the transfer of the technology to the farmers.

Method Used in Transferring the Technology to the Farmers.

The on-farm adaptive research (OFAR) approach for improved technology transfer to farmers was used. In this approach, the technology is demonstrated on the farmer's field with him or the researcher managing the trial. In this case, the trial was researcher-managed but farmer-executed. The advantage of this approach is that it enables the farmers to have the full practical knowledge of handling the technology themselves. Each variety came with a package of fertilizer recommendation, plant population and other cultural practices. The trial with SAMSORG-20 started with 19 farmers who were gradually reduced to 10 by the time SAMSORG-14 was fully introduced in 1986/87. In each case, each farmer planted 0.1 ha of his land with each of the two varieties each year.

Initial Adoption of the Two Varieties

Farmers are always willing to accept innovations that lead to improvement in their yield and income, as long as such technologies fit into their socio-economic base. In the case of SAMSORG-20 variety, the relatively high potential yield is only realisable in the northern Guinea savanna if the rainfall is normal. Unfortunately, since its introduction, the rainfall has been lower than normal and therefore the yields continued to decline, remaining lower than the potential yield (Table 2).

The low yields discouraged the farmers so much that by 1986/87, only very few farmers grew SAMSORG-20. In terms of net income from production, SAMSORG-14 did better than SAMSORG-20 because it commands higher price in the market than other sorghum varieties. A comparison of the net income from the production of SAMSORG-20 and SAMSORG-14 shows that for each year, the net income from SAMSORG-14 was higher than that obtained from SAMSORG-20.

Table 2. The average yields from SAMSORG-20 and SAMSORG-14 in northern Guinea savanna, Nigeria.

Year	Average yield (kg/ha)	
	SAMSORG-20	SAMSORG-14
1982/83	1560	NA
1983/84	1491	NA
1984/85	1121	NA
1985/86	1224	NA
1986/87	1221	1301
1987/88	1822	2034
1988/89	NA	2257

NA = Not available (not included in the experiment for that year).
Source : IAAR : Cropping Sheme Reports.

In terms of colour, the white colour of SAMSORG-14 was preferred to the yellow colour of SAMSORG-20 by farmers for food. They have insisted that food prepared with SAMSORG-20 neither stored well nor had good taste. In terms of the usefulness of the plant stalk, SAMSORG-20 stalk was only useful for feeding livestock, whereas SAMSORG-14 was very useful in making fence, for roofing and as fire wood because of its much greater length. For this reason, SAMSORG-14 was preferred to SAMSORG-20.

The attributes of SAMSORG-14 which appealed to the farmers were first demonstrated at the field of the farmer who was used in the first year of the trial. When the farmer was interviewed in 1994, he revealed that at the year he first grew SAMSORG-14, he received so many requests for the seed from his neighbours that he could not meet the demand. Consequently, he sold his seed to the ADP which arranged for the subsequent multiplication by its out-growers. Thus it was from the ADP that other farmers not involved in the trial obtained seed of SAMSORG-14. Since 1989/90, the variety has been the most popular variety among the farmers and today no farmer in the northern Guinea savanna grows SAMSORG-20.

Extent of Popularity and Adoption of SAMSORG-14 by 1994

The follow up interview of farmers involved in the initial adoption of SAMSORG-20 and SAMSORG-14 was conducted in late 1994 to determine if SAMSORG-14 is still grown by farmers and to seek their views on its present performance. Five of the farmers were interviewed and some of their views are summarised below:

- SAMSORG-14 is grown by all the farmers in the two villages where the trial was first conducted and by many farmers in the surrounding villages.

- It is preferred to other varieties because it is still high yielding, drought tolerant, has good taste, and fetches higher prices.
- When the grain is polished it is cooked and eaten as rice.

- It is used to make fura, a local drink taken with cow milk and sold by Fulani women.

- Although the popularity of maize growing has reduced the level of its cultivation, SAMSORG-14 grown with the recommended fertilizer rate yielded as much as maize.

Conclusion

The study has shown that farmers go for technologies that meet their needs. While SAMSORG-20 was rejected in the end, because it did not meet farmers' expectations, SAMSORG-14 remained with the farmers, and continued to grow in popularity, because it was found useful by them. The OFAR method of testing technology on farmers' fields allows the farmers to properly evaluate all aspects of a technology before it is considered for adoption. It is one of the surest methods of transferring promising technologies to farmers.

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On-Farm Testing of Crop Varieties as Component Technology in Sorghum/Millet/Cowpea Mixture

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Abstract

The problem of lack of mass adoption of improved varieties of traditional staple food crops like sorghum, millet and cowpea could be better addressed through farmer managed, on-farm trials. A study was conducted at Yandoto and Zogarawa villages in the Sudan savanna ecological zone of Nigeria to evaluate the agronomic performance of one improved variety each of sorghum (SAMSORG-4), millet (SAMMIL-6), and cowpea (SAMPEA-7) in comparison with local varieties; determine the financial costs and benefits of production; and assess the perception of farmers with a view to enhancing the adoption process. At each location, 25 farmers were selected on the basis of their expressed interest after they had been appraised about the study objectives through pre-season village meetings. The results showed that the grain yield and acceptability of improved cowpea, SAMPEA-7, were consistently higher than those of the local variety at both locations. Improved sorghum variety, SAMSORG-4, yielded higher than the local variety at Yandoto, but not at Zogarawa because its medium maturity period is too long for this location. The sorghum hybrid, ICSH 89002NG, used as a replacement for SAMSORG-4 at Zogarawa in 1993 was more acceptable to farmers because of its earliness. Farmers were consistently indifferent to the improved millet, SAMMIL-6, because of its lack of superiority over the local variety. Labour requirements were consistently similar among farmers across the sites. The improved varieties resulted in higher financial returns than local varieties.

Résumé

Le problème de la non-adaptation massive des variétés améliorées de cultures traditionnelles telles que le sorgho, le mil et niébé dans les zones tropicales semi-arides d'Afrique Occidentale pourrait être mieux résolu grâce à des essais en milieu paysan sous conduite paysanne. Une étude a été réalisée dans des localités de la Savane Soudanienne et Nord Guinéenne du Nigéria afin d'évaluer la performance agronomique de la variété améliorée de sorgho SAMSORG-4, de mil SAMMIL-6 et de niébé SAMPEA-7 par rapport aux variétés locales des paysans, de déterminer les coûts et avantages financiers de production, de connaître le point de vue des paysans et d'accélerer le processus d'adoption.

Vingt-cinq paysans ont été retenus sur la base de leur intérêt manifesté dans chaque localité et après avoir été évalués quant aux objectifs du projet lors de réunions villageoises organisées avant la campagne dans chaque localité. Une superficie de 0,2 ha a été délimitée dans le champ de chaque paysan puis divisée en deux portions égales.

L'une a été semée de variétés composantes améliorées et l'autre de variétés composantes locales dans une association de trois cultures suivant la préférence des paysans. Les traitements ont été établis dans un dispositif de bloc complet randomisé avec un paysan servant de répétition. Toutes les pratiques d'aménagement étaient conformes aux pratiques culturales habituellement utilisées par les paysans, mais des insecticides ont été appliqués par les chercheurs sur le niébé.

Les résultats indiquent que le rendement en grain de la variété de niébé SAMPEA-7 a été constamment supérieur à celui des variétés locales dans tous les sites. Les rendements des variétés améliorées de sorgho et de mil n'étaient pas constamment supérieurs à ceux des variétés locales mais variaient suivant la localité et la saison. Bien que les variétés améliorées aient permis d'obtenir une augmentation des revenus en comparaison avec les variétés locales, les paysans de Zogarawa (Savane Soudanienne) préféraient cultiver leurs mils et sorghos locaux (le sorgho précoce était préféré). Néanmoins, les paysans de Yandoto (zone de transition Savane Nord guinéenne/Savane Soudanienne) aimeraient cultiver toutes les variétés améliorées, de préférence aux variétés locales. La variété améliorée de niébé SAMPEA-7 était constamment préférée aux variétés locales par les paysans dans toutes les localités.

Introduction

Sorghum (*Sorghum bicolor* (L.) Moench), millet (*Pennisetum americanum* (L.) Leeke) and cowpea (*Vigna unguiculata* (L.) Walp.) are the most widely cultivated foodcrops in the semi-arid areas of Nigeria. The small-scale farmers who constitute the bulk of the producers mostly cultivate indigenous varieties. Most of the improved varieties have not been adopted apparently because they do not fit well into circumstances and cropping goals of small-scale farmers. Improved varieties have been developed for sole cropping (Egharevba, 1979; Hays and Raheja, 1979) while the farmers cultivate these crops mostly in crop mixtures and relay systems (Curtis, 1965, Norman, 1974).

The investigation reported in this paper was carried out to compare the agronomic performance of improved varieties of sorghum, millet, and cowpea with that of the indigenous varieties cultivated by farmers; assess farmers' perception of improved varieties; and evaluate the financial costs and benefits of production with a view to enhancing the overall process of adoption of the improved varieties by small-scale farmers.

Materials and Methods

The trial was conducted on farmers' fields at Yandoto (lat. 12° 10'N; long° 06° 42'E) in Sokoto State of Nigeria and at Zogarawa (lat. 11° 39'N; long° 08° 27'L) in Kano State. Yandoto location falls within the southern part of the Sudan savanna, while Zogarawa is in the drier central Sudan savanna. In the Sudan zone, rainfall is unimodal, varying from 600 - 900 mm, with the length of the season varying from 95 - 140 days. The soil type is basically non-leached ferruginous soil derived from Lithosols and sandy materials.

Farmers' practices

Sorghum, millet and cowpea are planted as rainfed crops in upland soils. Farms around the homestead are permanently cropped but soil fertility is maintained with farmyard manure and inorganic fertilizers. Outlying farms are subjected to varying periods of fallow, depending on population pressure. Farming activities are highly dependent on hand hoes, although use of oxen in land preparation is common at Yandoto. Ridge cultivation is widespread in the study area. Most of the farm labour are derived from family sources with adult males contributing greater percentage than females. Because of the short duration of the rainy season, all the crops are planted at the same time. Individual fields vary in respect of cropping history, degree of shade due to economic trees (e.g., *Parkia* spp.), time of planting, weeding, row arrangement in mixture, and plant densities.

Treatments, trial design, operations and observations

There were basically two main treatments. These were farmer's indigenous variety of each of the three crops on one hand and one improved variety each of sorghum (SAMSORG-4), millet (SAMMIL-6), and cowpea (SAMPEA-7), on the other. The improved varieties were identified from an earlier on-station experiment. SAMSORG-4 is a medium maturing, white seeded sorghum variety with tall plants. SAMMIL-6 is a moderately tall variety of millet, maturing between 47-51 days, with good level of disease resistance. It was derived from a cross between Akontess and Nigerian composite. SAMPEA-7 is semi-erect, photoperiod insensitive cowpea with brown rough testa. ICSH 89002NG, a single crop sorghum hybrid, early in maturity (105-115 days), with moderate plant height, semilax panicles and cream coloured grains, was used as a replacement for SAMSORG-4 at Zogarawa in 1993. With the exception of ICSH 89002NG, which is an ICRISAT variety, all the improved varieties were developed and released by IAR, Samaru, Nigeria.

A total of 25 farmers were selected at each site based on their expressed interest after they had been informed about the study objectives through initial pre-season village meetings. An area of 0.2 ha was marked out in each field. The field was then subdivided into two, one for each of the two treatments. In cases where farmers did not cultivate the three crop mixture (sorghum/millet/cowpea), each half was further subdivided into two to accommodate the sole crop and the two-crop mixture.

The treatments were applied by the farmers in a randomized complete block design with each farmer serving as a replicate. The trial was basically farmer managed. Researchers were involved in collection of input/output data, including daily record of all farming activities and supervision of insecticide application to cowpea. Application of insecticide involved three applications, at 10-day interval, of a tank mixture of 50 g a.i./ha cypermethrin and 250 g a.i./ha dimethoate, commencing from first anthesis. An informal post-season technology evaluation exercise was carried out in each village, with each participating farmer to monitor the farmers' overall perception of the study and treatments. A bag of 50 kg compound fertilizer (15-15-15) was given to each participating farmer to apply to millet and sorghum after the first weeding. All the crops planted in each plot were harvested by the farmers for yield determination.

Results

Grain yield of sorghum, millet and cowpea

At Yandoto, SAMSORG-4 out-yielded the local variety but the difference was not significant in 1993 (Table 1). There was no significant difference between grain yields of improved and local millet varieties at Yandoto in both years. By contrast, SAMPEA-7 consistently outyielded the local varieties in both 1992 and 1993.

At Zogarawa, SAMSORG-4 was inferior in yield to the local variety in 1992, probably because it did not produce grains in some plots since the maturity cycle was longer than the duration of rain-fed period. It was replaced by the hybrid, ICSH 89002NG, as the farmers were interested in early maturing sorghum. In 1993, the yield of the hybrid sorghum was statistically at par with that of the local variety. For millet, there was no significant difference between the grain yield of the improved variety and the local cultivar in both years. On the other hand, SAMPEA-7 consistently out-yielded local cowpea varieties in both 1992 and 1993.

Table 1. Grain yields of sorghum, millet and cowpea on farmers' fields at Yandoto and Zogarawa, Nigeria.

Crop variety	Grain yield (kg/ha) at:			
	Yandoto		Zogarawa	
	1992	1993	1992	1993
Sorghum				
SAMSORG-4	2489	1887	295	-
ICSV 89002-NG				956
Farmer's local	2110	1598	400	924
SE ±	106.0	125.7	40.4	115.6
Millet				
SAMMIL-6	2188	1512	386	597
Farmer's local	2212	1560	453	519
SE ±	67.9	118.1	101.6	110.1
Cowpea				
SAMPEA-7	1306	1325	203	454
Farmer's local	1128	1060	135	235
SE ±	28.4	87.9	32.5	38.4

Labour requirements

Table 2 shows that the labour requirement for improved varieties were not different from those of the local varieties at Yandoto for all the crops. The highest amount of labour was utilized in harvesting, followed by weeding. At Zogarawa, most of the labour for production of sorghum/millet/cowpea mixture in 1992 was consumed by land preparation, weeding, and remoulding (Table 3). In 1993, most of the labour used to produce the sorghum/millet mixture at Zogarawa was devoted to the above three operations in addition to harvesting. Harvesting of improved sorghum hybrid took less labour because the plants were shorter than those of the local varieties. Generally, the higher the yield, the higher was the labour required for harvest.

Table 2. Labour requirements for production of a hectare of millet/cowpea relay crop and sole sorghum crops at yandoto, Nigeria

Cultural operation	Millet/cowpea relay crop				Sole sorghum			
	1992		1993		1992		1993	
	Improved cultivar	Local cultivar	Improved cultivar	Local cultivar	Improved cultivar	Local cultivar	Improved cultivar	Local cultivar
	(man hours/ha)							
Land preparation	52	54	30	30	54	56	30	30
Planting	24	22	25	21	10	10	15	10
Weeding	86	86	73	73	43	43	41	42
Fertilizer application	4	4	5	5	4	4	5	5
Remoulding	7	7	8	8	8	8	8	9
Insecticide spraying	4	4	4	4	-	-	-	-
Harvesting	194	194	213	214	96	96	129	123
Total	317	368	358	355	215	215	228	219

Table 3. Labour requirements for production of a hectare of sorghum/millet/cowpea mixture, sorghum/millet mixture and sole cowpea crop at Zogarawa, Nigeria.

Cultural operation	1992		1993			
	Sorghum/Millet/ cowpea mixture		Sorghum/Millet mixture		Sole Cowpea	
	Improved cultivar	Local cultivar	Improved cultivar	Local cultivar	Improved cultivar	Local cultivar
	(man hours/ha)					
Land preparation	163	162	78	78	76	73
Planting	35	23	27	24	20	39
Weeding	158	150	71	71	68	68
Fertilizer application	15	15	13	12	-	-
Remoulding	115	121	54	57	3	3
Insecticide spraying	18	12	-	-	19	16
Harvesting	79	59	63	78	71	44
Total	582	542	306	320	257	243

Financial costs and returns

Labour constituted about 50% of the total cost of production at Yandoto (Tables 4 and 5). In 1992, returns per unit of labour were NGN38.52 and 38.52 for improved and local varieties in millet/cowpea mixture. Similar trend was observed in 1993. However, for sole sorghum at Yandoto, returns per unit of labour were lower in 1993 than in 1992 because of lower yields, higher cost of fertilizer, and depreciation. At Zogarawa (Tables 6 and 7) returns per unit of labour were lower for improved varieties in 1992 than in 1993 because of the generally lower yields, particularly of sorghum. In 1993 returns per unit of labour were negative for local sole cowpea which implied that the farmer operated at a loss. The grain yield could not adequately pay for the cost of the insecticide application.

Farmers' reactions

Data on the reaction of farmers to the improved varieties showed that in 1992, all the farmers at Yandoto indicated that they would adopt the improved variety of each of the three crops. By contrast, at Zogarawa, only improved cowpea was acceptable to 100% of the farmers, who generally were not interested in adopting the improved sorghum and millet varieties. In 1993, however, 100% of the farmers would adopt the early maturing sorghum hybrid. Interest in improved millet was below expectation. At Yandoto, where the farmers still maintained high interest in cultivating all the improved varieties, interest in the improved millet was on the decline.

In respect of the varietal traits of interest to farmers, cowpea grain size and earliness were consistently the most important considerations at Zogarawa in both years. Grain colour, grain size, and earliness were the preferred traits for sorghum at Yandoto; with the exception of grain colour, the traits of sorghum preferred by Zogarawa farmers were similar to those preferred by Yandoto farmers. Earliness was the most consistently preferred trait at Yandoto but not at Zogarawa.

With respect to the preferred cropping system, all the participating farmers at Zogarawa would like to grow sorghum/millet mixture and pure crop cowpea. At Yandoto, however, all the farmers would like to produce millet/cowpea mixture and pure crop sorghum.

Table 4. Costs and returns in production of one hectare of millet/cowpea relay crop and sole sorghum at Yandoto (1992 wet season), Nigeria.

	Millet/cowpea relay crop [a]				Sole sorghum [a]	
	Improved variety		Local variety		Improved variety	Local variety
	Millet	Cowpea	Millet	Cowpea		
Output (kg/ha)	2188	1306	2212	1126	489	2110
Gross revenue (NGN/ha)	17,012		15,660		467	6330
Labour cost (NGN/ha)	1,484		1,472		860	868
Other costs (NGN/ha)						
Fertilizer	320		320		320	320
Insecticide	500		500		NA	NA
Depreciation	325		325		250	250
Bags	350		340		210	210
Total cost (NGN/ha)	2,979		2,957		1,680	1,648
Returns/ha (NGN)	14,033		12,703		5,787	4,682
Returns/unit of labour (NGN)	41.83		38.52		30.92	25.58

[a]: Sorghum and millet grains were valued at NGN3/kg; cowpea at NGN8/kg; labour at NGN4/hr; fertilizer at NGN1.60/kg; NA = Not applicable.

Table 5. Costs and returns in production of one hectare of millet/cowpea relay crop and sole sorghum at Yandoto (1993 wet season), Nigeria.

	Millet/cowpea relay crop [a]				Sole sorghum [a]	
	Improved variety		Local variety		Improved variety	Local variety
	Millet	Cowpea	Millet	Cowpea		
Output (kg/ha)	1,512	1,325	1,860	1,060	1,867	1,598
Gross revenue (NGN/ha)	21,192		18,180		6,535	5,593
Labour cost (NGN/ha)	2,148		2,130		1,368	1,314
Other costs (NGN/ha)						
Fertilizer	600		600		600	600
Insecticide	960		960		NA	NA
Depreciation	500		500		500	500
Bags	250		250		250	250
Total cost (NGN/ha)	4,458		4,440		2,718	2,664
Returns/ha (NGN)	1,673		13,740		3,817	2,817
Returns/unit of labour (NGN)	46.75		38.70		16.74	13.37

[a]: Sorghum and millet grains were valued at NGN3/kg; cowpea at NGN8/kg; labour at NGN4/hr; fertilizer at NGN1.60/kg; NA = Not applicable.

Table 6: Costs and returns in production of one hectare of sorghum/millet/cowpea mixture at Zogarawa (1992 wet season), Nigeria.

	Improved variety*			Local variety		
	Sorghum	Millet	Cowpea	Sorghum	Millet	Cowpea
Output (kg/ha)	295	386		204	400	453 135
Gross revenue (NGN/ha)		3,675			3,639	
Labour cost		1,328			2,168	
Other costs						
Fertilizer		320			320	
Insecticide		500			500	
Depreciation		75			75	
Bags		90			100	
Total costs (NGN/ha)		3,313			3,163	
Returns/ha (NGN)		362			476	
Returns/labour (NGN)		4.62			4.88	

*: Sorghum and millet grains were valued at NGN3/kg each; cowpea at NGN8/kg, labour at NGN4/hr and fertilizer at NGN1.6/kg.

Table 7. Costs and returns in production of one hectare of sorghum/millet mixture and of sole cowpea at Zogarawa (1993 wet season), Nigeria.

	Sorghum/Millet mixture				**Sole cowpea**	
	Improved variety		Local variety		Improved variety	Local variety
	Sorghum	Millet	Sorghum	Millet		
Output (kg/ha)	956	597	924	519	454	235
Gross revenue (NGN/ha)	5,436		5,051		5;448	2,820
Labour cost	1,674		1,920		1,542	1,458
Other costs						
Fertilizer	600		600		NA	NA
Insecticide	NA		NA		960	960
Depreciation	500		500		500	500
Bags	250		250		250	250
Total costs (NGN/ha)	3,024		3,270		3,252	3,168
Returns/ha (NGN)	2,412		1,781		2,196	-348
Returns/labour (N)	8.64		5.56		8.55	-1.43

Sorghum and millet grains were valued at NGN3.50/kg; cowpea at NGN12/kg; labour at fertilizer at NGN3/kg; NA = not applicable

Discussion

Grain yields of sorghum, millet and cowpea were generally higher in Yandoto than in Zogarawa, probably because Yandoto is in the wetter part of the Sudan savanna agroecology. This partly explains why farmers at Zogarawa considered the maturity period of SAMSORG-4 too long and preferred earlier maturing varieties; it may also partly explain why these farmers chose to cultivate sorghum/millet mixture and pure crop cowpea. By contrast, farmers at Yandoto chose to grow pure crop sorghum as well as cowpea relayed into the millet, usually sown with the first rains.

It is interesting that the total labour requirements were similar at the two contrasting locations in both years. This suggests that labour was not a constraint to the adoption of any of the improved varieties used in the present study. Small scale farmers have a tendency to adopt changes that are not labour intensive. Williams (1972) reported that farmers reverted back to use their local variety because the improved variety was more labour demanding.

Improved cowpea variety, SAMPEA-7, was strikingly profitable in terms of returns per unit of labour at Zogarawa, compared to the local variety that was produced at a loss. Thus, SAMPEA-7 was consistently preferred to the local cowpea variety by small-scale farmers who also preferred local millet variety to the improved millet, SAMMIL-6. For sorghum, the improved variety was preferred only when the maturity cycle fitted well with the length of the growing season. It is evident that farmers would prefer improved to local varieties only if the former meet their socio-economic circumstances, preferences and goals.

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Technologies for Cowpea Production Based on Genetic and Environmental Manipulations in the Semi-Arid Tropics

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Abstract

Cowpea (*Vigna unguiculata* (L.) Walp.) together with the cereals (millet, sorghum, and, to some extent, maize and rice) are the staple food grains of semi-arid tropics in West and Central Africa. Its haulm is used as fodder; in addition cowpea enriches the soil with biologically fixed nitrogen. The adaptation of local landrace varieties has been dramatically altered due to climatic change since 1970s. This had resulted in the loss of cowpea productivity in the sub-region, and prompted the SAFGRAD project to conduct cowpea improvement collaborative research with the International Institute of Tropical Agriculture (IITA) and national agricultural research systems (NARS). The objectives of the SAFGRAD project were to identify cowpea production constraints, develop new and appropriate production technologies, and to make these technologies available to member countries for adaptation/adoption. The region's cowpea production constraints, production strategies and new production technologies are briefly reviewed.

Résumé

Le niébé (*Vigna unguiculata* (L) Walp) constitue avec les céréales (mil, sorgho et dans une certaine mesure le maïs et le riz) la culture vivrière de base en Afrique Occidentale et Centrale Semi-Aride. Ses fanes sont utilisées pour engraisser les ruminants en vue d'obtenir de la viande et du lait. En association ou en rotation avec les céréales, le niébé peut enrichir le sol par l'azote biologiquement fixée. L'adaptation des landraces locaux a été considérablement altérée depus les années 70 en raison du changement climatique. Cela a entraîné une baisse de la productivité du niébé dans la sous-région et a incité le projet SAFGRAD à mener la recherche collaborative pour l'amélioration du niébé avec l'Institut International d'Agriculture Tropicale (IITA) et les Systèmes Nationaux de Recherche Agricole (SNRA). Les objectifs de recherche consistaient à identifier les contraintes à la production du niébé, à mettre au point des technologies nouvelles et appropriées de production et à mettre ces technologies à la disposition des pays membres pour leur développement et production agricoles. De nouvelles technologies de production ont été produites au cours des 15-16 dernières années. L'évaluation de ces technologies dans la sous-région est propice à la formulation de différentes stratégies de production parmi lesquelles les décideurs peuvent choisir les plus appropriées pour l'introduction et le développement d'une production agricole scientifique et durable dans leurs pays respectifs. Les contraintes à la production du niébé, les stratégies de production, et les nouvelles technologies de production assurant aux paysans de la sous-région la sécurité alimentaire sont brièvement examinées.

Introduction

In 1990, approximately 186.7 million people lived in West and Central Africa. About 70 to 90% were either agricultural or low income urban settlers. Cereals (millet, sorghum and, to some extent, maize and rice) and cowpea are the staple food grains in the semi-arid zone. This zone has a comparative advantage in cereal production (Salinger and Stryker, 1993) and exports cereals to coastal urban centres.

Cowpea is often the only crop that survives severe drought in the semi-arid zones (SAZs). Also, cowpea grain, containing about 22% protein, constitutes a major source of cheap, good quality protein for poor people. For example, it is estimated that cowpea supplies about 40% of the daily protein requirements to most of Nigeria's population. Cowpea is also produced as fodder for ruminants, thereby enabling integrated crop and livestock production. In addition, when grown in rotation or association with cereals, cowpea may enrich the soil with biologically fixed nitrogen up to 25 kg per ha for pure-stand cropping (Mulongoy, 1986). Indeed, Yilala (1992) has observed a large increase in millet grain and straw yields due to millet/cowpea intercropping as compared to pure-stand millet cropping in unfertilized fields in Sahelo-Sudanian zones.

In the 1970s, cowpea production in the SAZs was adversely and severely affected due to drought, insect pests, diseases, and *Striga* attack. This prompted the establishment of a collaborative research programme implemented by the SAFGRAD Project together with IITA and NARS, particularly the national cowpea program of Burkina Faso. The objectives of the research were to identify cowpea production constraints and to develop new and appropriate production technologies to overcome them, thereby ensuring food security to peasant farmers. This paper reviews agro-ecological zones, cowpea production constraints, strategies for cowpea production, as well as the production technologies developed by the SAFGRAD Project during 15 years.

Major Agro-Ecologies of Semi-Arid Tropics in West and Central Africa

Semi-arid West and Central Africa can be sub-divided into two major agro-ecological zones which are described briefly below.

Sahelo-Sudanian zones

The monomodal rainfall varies from 250 to 900 mm with a cropping season of three to four months. Rainfall is generally poorly distributed at the beginning and towards the end of the crop season. Ambient temperature varies from as low as 10°C during the cold season to 42-48°C during the hot, dry season, and 24 to 45°C during the rainfed growing season. Wind velocities can exceed 80 km per hour at the beginning of the crop season. Predominant soils are Aridisols and Alfisols, for rainfed cropping conditions, while Vertisols occur in bottom lands, some of which are irrigated. Major crops are sorghum, millet, cowpea and groundnuts. Maize crop is being introduced and is generally cultivated around the household. Limited quantities of irrigated rice is also produced.

Moist Savanna

This area covers the northern Guinea savanna with monomodal rainfall and the southern Guinea savanna with bimodal rainfall. Precipitation varies from 900-1500 mm with a cropping season of 4.5 to 6.5 months. Ambient temperatures are mild (20 to 36°C); high wind velocities are not major constraints to crop production. Predominant soils include Alfisols and Oxisols; some Aridisols can be found in the northern Guinea savanna. Entisols (Psamments), in uplands, and Vertisols, in bottom lands, occur also. Major crops include sorghum, maize, rice, yams, cassava, cowpea, groundnuts and cotton. Soybean is also grown in this agro-ecology.

Cowpea Production Constraints

Cowpea production in semi-arid West and Central Africa is adversely affected by many constraints which are outlined below.

Climatic factors

These include 3 to 5 months of rainfall that is erratic, insufficient and poorly distributed and occurs as tropical rainstorms at the onset of the growing season. Ambient air temperatures during the crop season vary from 24 to 45°C; but soil temperatures in bare soils may be up to 38 to 48°C. At the beginning of the crop season (May to early-July), wind velocities, particularly in the Sahel, often exceed 80 km per hour . As such, they generate sandblasts which cause severe damage to seedlings and even established crops. They cause soil erosion during the dry season and so reduce soil fertility.

Edaphic constraints

Soils of the sub-region evolved from acidic parental rocks (granite, gneiss, sandstone and schist) which inherently have low nutrient contents. Also, because of the rapid destruction of the organic matter due to high temperatures, plant nutrients are either leached down with percolating water or carried away by runoff. Soil acidification can be a major problem, particularly in the moist savanna zone.
With the exception of Oxisols, soils are characterized by poor structure, low water infiltration rate, soil surface sealing and crusting, soil compaction, and low water retention capacity.

Biotic constraints

The major biotic constraints include weeds, parasitic flowering plants, insect pests, and diseases. Noxious weeds, such as *Imperata cylindrica* can be a problems in the moist savanna zone under continuous cultivation conditions. Among the parasitic flowering plants, *Striga gesnerioides* is a problem under continuous cultivation conditions in the Sahel, Sudan savanna and some parts of moist savanna zone while *Alectra vogelii* parasitizes cowpea in the moist savanna zone and in hydromorphic soils in the Sahelo-Soudanian zone.
Several insect species cause severe damages on cowpea crops. The major ones include aphids (*Aphis craccivora* Koch), thrips (*Megalurothrips sjotedti* Tryb.), pod sucking bugs (*Anoplocnemis curvipes, Clavigralla tomentoscicolis*, etc.), pod borers, (*Maruca*

testulalis) and storage weevils (*Callosobruchus maculatus* F.). Important diseases include bacterial blight (*Xanthomonas campestris* pv. vignicola), Macrophomina blight (*Macrophomina phaseolina*), brown blotch (*Colletotrichum capsici* and *C. truncatum*), Septoria leaf spot (*Septoria vignae*), scab (*Elsinoe phaseoli*) and several virus diseases, especially the cowpea aphid-borne/blackeye cowpea mosaic virus complex.

Socio-economic and cultural constraints.

These include:

. Inadequate number of skilled scientists and technicians working in agricultural research and extension services;
. Traditional subsistence farming system using landrace varieties; low input agriculture; lack of integration of livestock, tree planting and agricultural production systems, as well as frequent bushfires;
. A high level of illiterate people (90%) involved in agricultural production;
. Absence of, or high cost of, agricultural inputs;
. Longtime neglect of agricultural research, particularly for food crops.

Strategies for Cowpea Production

Four alternative strategies may be considered in cowpea production in Africa. They include traditional, improved traditional, intermediate, and modern production strategies.

Traditional cowpea production strategy

Productivity in traditional farming system is a function of: land availability, labour, amount of rainfall received and its distribution, soil fertility (which depends on the quality and duration of the fallow period and the use of some organic manure), the yielding ability of landrace varieties, and storage capacity of produce.
Landrace varieties are a mixture of different adapted and compatible genotypes. They do not have any maximum yield advantage, but rather a good population buffering capacity against environmental hazards which guarantees farmers' basic food security.
Three types of landrace varieties are found in traditional cowpea farming system, namely, daylength sensitive, daylength neutral, and partially daylength sensitive varieties. Daylength sensitive varieties, commonly found in the northern Guinea and Sudan savannas, are sparsely sown in mixture with cereals from late June to late July; being prostrate, they creep underneath the cereal to provide complete ground cover by mid to late August. They flower from mid-September to late October; and yield from 200 to 300 kg of grains per ha and from 1000 to 2000 kg of fodder per ha.

Daylength neutral varieties are also extensively grown in the moist savanna zone, where, in contrast to daylength sensitive varieties, farmers sow them at the onset of the rains in May for harvesting in July-August. They are erect or semi-erect. They yield 200 to 500 kg of grains per ha, and 700 to 2000 kg of fodder per ha. Partially daylength sensitive varieties are found in the Sahel; their grain and fodders yield are about 300 kg ha^{-1} and 700-2000 kg/ha, respectively.

Improved traditional cowpea production strategy

Production factors under this strategy are similar to those of the traditional production strategy except that it employs new improved, low input production technologies which include: proper land tillage techniques; crop rotations; use of improved fallow with legume cover crops for 2 to 5 years to restore soil fertility and physical properties; use of improved cultivars adapted to the respective agro-ecological zone; sowing at the optimum date and plant population density; erosion control measures; etc. The strategy's thrusts are sustainable production and protection against environmental degradation.

The formulation, implementation, and effectiveness of such a strategy require both strategic and applied research for the identification of production constraints and the development of appropriate production technologies to overcome the constraints as well as effective extension services. All these should be coupled to enabling government, socio-economic policies.

Intermediate cowpea production strategy

New improved production technologies are important elements of this strategy. The goal is to obtain about 80% of the maximum yield with significantly less inputs (Sanchez and Salinas, 1981). Landrace varieties are replaced by improved cultivars that have high yield potential and high genetic buffering capacity as well as tolerance of drought and excess moisture, and resistance to major diseases, insect pests, and *Striga*.

Productivity under this strategy is equal to or better than that of improved traditional strategy at low uses of inputs; it approaches maximum productivity achieved under modern strategy at high uses of inputs. The intermediate strategy offers farmers an opportunity to evolve progressively, without great social disruption, from traditional farming to modern farming systems as they gain access to more capital and new knowledge. To be effective, this strategy should be supported by operational and efficient agricultural research and extension services, and sound government agricultural policies compatible with a sustainable agricultural development.

Modern cowpea production strategy

Productivity in modern cowpea farming system is a function of: land availability; number and skill of labour; amount and distribution of rainfall; appropriate production, storage and utilisation technologies; availability and accessibility of inputs to farmers; and sound marketing infrastructure and distribution systems.

Appropriate production technologies include: high yielding cultivars specifically adapted to prevailing environmental conditions; seed rate and timely sowing; proper weed control; rate and time of application of chemical and organic fertilizers; management of diseases and insect pests; and technologies for harvesting, storage and processing of the harvested products.

Maximum achievable grain yields per hectare, in the absence of drought, are 2000 to 2500 kg in northern Guinea savanna, 1500 to 2000 kg in Sudan savanna and 1000 to

1500 kg in the Sahel. To be efficient, modern cowpea production requires highly skilled farmers, efficient agricultural research and extension services, continuous supply of agricultural inputs, including credits, proper infrastructures and an efficient marketing system.

Cowpea Production Technologies

The IITA-SAFGRAD cowpea project, in collaboration with NARS, spent 15 years — from 1978 to 1993 — to develop new and appropriate production technologies through genetic as well as environmental manipulations. The new technologies are described below:

Technologies developed through genetic manipulations

Local varieties: The climatic change experienced since early 1970s has resulted in a southwards shift in the zones of adaptation of local varieties. Thus, Sahelian varieties became adapted to the Sudanian zone, while the Sudanian varieties were adapted to the northern Guinea savanna zone. However, during wet years the new varieties were susceptible to attack by major diseases in their new environments (Cowpea Agronomy, IITA-SAFGRAD, 1981-85; Muleba *et al.*,1991).

***Improved cultivars*:** New cultivars genetically well buffered against environmental variations were developed. They are high yielding; widely adapted; and resistant to diseases, drought and heat stress; some also possessed tolerance to excess moisture, resistance to *Striga*, and tolerance to insect pests (RENACO, 1990, 1992 a & b, 1993; INERA, 1993). Their profile is described in Table 1.

Technologies developed through environmental manipulation

***Crop season characterization*:** The crop season has been defined for the Sahel, Sudan savanna and northern Guinea savanna agro-ecological zones (Muleba, 1988a). This included the determination of its start and its end, rainfall rate and partitioning, and the probability of dry, hot spells and the months during which they occur. This information enabled breeding and selection, for better adaptation, i.e., cultivar growth cycle and agronomic attributes in relation to the physical environment (Muleba, 1988b; Muleba *et al.*, 1991a).

Land preparation: Ploughing soils by hand-held hoe, tractor or animal traction prior to planting mitigates the effects of drought and increases yields in all agro-ecological zones, especially the Sudan savanna, compared to planting on untilled soils in the absence of *in situ* mulch; the latter can be a good substitute for soil tillage if the cover crop provided an adequate soil cover during the preceding year. This practice, however, requires the use of herbicides (systemic herbicide such as glyphosate; contact herbicide, e.g., Paraquat; pre-emergence herbicides, e.g., metolachlor and others) (Cowpea Agronomy, IITA-SAFGRAD, 1981-87).

***Seed-bed preparation*:** In the Sudan savanna (but not in northern Guinea savanna, the Sahel and sandy soils in the Sudan savanna), the tied ridging technology improves soil water retention and infiltration, increases soil water reservoir, mitigates drought damage conserves soil and increases yields, even during wet years (Cowpea Agronomy, IITA-SAFGRAD, 1981-85; Muleba & Brockman, 1991). Ridging based on contour lines in slopy fields reduces runoff and erosion and provides good soil conservation measures in all agro-ecological zones.

Crop residue management: The withdrawal of crop residues (instead of leaving them as *in situ* mulch or ploughing them under) for animal feed has a detrimental effect on soil physical properties and fertility; it also reduces the yield of the succeeding crop (Cowpea Agronomy, IITA-SAFGRAD, 1983-87).

Windbreaks: Windbreaks are requisites for controlling wind erosion in the Sahel and Sudan savanna zones. They protect crops against mechanical damage, sandblast damage, and increased evapotranspiration. When combined with mulch, windbreaks can boost cowpea productivity by more than 15% in the Sahel, compared to a check without windbreak treatment (Cowpea Agronomy, IITA-SAFGRAD, 1985-87). In the absence of windbreaks, wind erosion can be controlled through the use of tied ridges, or simple ridges perpendicular to the predominant wind direction. These practices should be combined with *in situ* mulch from crop residues.

Soil improvement: Phosphorus is the most limiting soil nutrient element for cowpea production. It is usually applied at about 22 kg P ha^{-1} from soluble phosphatic fertilizers or 44 kg P ha^{-1} from natural West African phosphatic rock fertilizers. At such a rate, P stimulates the uptake of other essential nutrient elements (such as nitrogen, potassium, calcium, etc.). Phosphorus fertilizers used with *in situ* mulch in semi-arid zones not only increase cowpea yield during rainy years, but also minimize losses during dry years. In addition, P fertilizers applied on a cowpea crop have a positive residual effect of P and N on the subsequent cereal crop. This makes cowpea a good preceding crop in cowpea-cereal rotations (Cowpea Agronomy, IITA-SAFGRAD, 1983-87).

Sowing date: The optimum sowing date is mid-July (for moist savanna and Sudan savanna zones) and late June (i.e., at the on-set of the rains) for the Sahel. In general, for the Sahel and Sudan savanna, cowpea should be sown on or after a day a rainfall of 15 mm or greater was received (Cowpea Agronomy, IITA-SAFGRAD, 1981-87, Muleba *et al*, 1991a).

***Plant population density and row spacing*:** The critical plant population density per hectare is 40,000 plants for daylength neutral cowpea and 22,000 plants for daylength sensitive cultivars (Cowpea Agronomy, IITA-SAFGRAD, 1981-96). Daylength sensitive varieties, sown at their optimum plant density, provide a complete ground cover in 30-45 days. Since both daylength neutral and sensitive cultivars exhibit a yield plateau when sown at the optimum date with plant density increasing from their critical level to 100,000 plants/ha, cowpea should be planted at 66,667 plants/ha, i.e. at 0.75 x 0.20 m (Cowpea Agronomy, IITA-SAFGRAD, 1983-86).

Table 1. Agronomic characteristics of some of the best SAFGRAD cowpea cultivars.

Cowpea characteristics	Cowpea cultvars									
	KVx 61.1	KVx 291-47-222	KVx 396-4-4	KVx 396-4-5-2D	KVx 396-18-10	KVx 402-5-2	KVx 402-19-1	KVx 414-2J 22-72	KVx 421-2 J	IAR7/ 180-4-5-1
Growth cycle: days to:										
Bud formation	40	36	33	40	37	35	35	35	35	40
Flowering	47	46	46	48	48	46	45	45	48	48
Maturity	70	70	68	72	71	66	68	67	68	75
Plant traits										
Plant type $	Spr.	SE	Spr	Spr	Spr	Spr	Spr	Spr.	Spr.	Spr.
Plant height	35cm	40cm	35cm	35cm	35cm	40cm	35cm	35cm	35cm	40cm
Leaf shape *	0-A,m	O-A,m	O-A,m	O-A,m	O-A,m	O-A,m	O-A,m	O-A,m	O-A,m	O-A,m
Reaction to diseases										
Bacterial blight	R	R	R	R	R	R	R	R	R	NR
Brown blotch	S	MR	R	R	R	R	R	R	R	R
Striga	HR	R	T	ST	T	T	R	S	S	S
Web blight	HS	HS	MR	MR	MR	MR	MR	MR	S	R
Scab	S	-	S	S	S	MR	MR	R	-	MR
Septoria	S	-	MR	MR	MR	MR	MR	-	-	MR
Virus	S	R	R	R	R	R	MR	R	S	MR
Reaction to insect pests										
Flower thrips	HS	S	S	ST	ST	S	S	MR	ST	S
Aphids	HS	S	S	ST	S	S	S	S	ST	S
Pod sucking bugs	HS	S	S	ST	S	S	S	MR	ST	S
Maruca pod borers	HS	HS	HS	HS	HS	HS	HS	-	-	-
Reaction to: £										
Drought	R	R	HR	HR	HR	HR	R	HR	R	ST
Heat stress	R	HR	HR	HR	HR	R	HR	R	ST	
Excess moisture	HS	T	T	T	T	T	T	ST	ST	T
Ecology of adaptation										
Sahel	GA	GA	GA	GA	GA	GA	GA	GA	GA	FA
Sudan savanna	FA	GA	GA	GA	GA	GA	GA	GA	GA	FA
Moist savanna	PA	FA	GA	GA	GA	GA	GA	FA	FA	GA
Seed traits										
Color	Mottled	white	White	White	Brown	White	White	White	Brown	White
Texture	rough	rough	rough	rough	rough	rough	rough	rough	rough	rough
100 kernel weight	16g	18g	18g	18g	16g	16g	16g	18g	18g	21g
Seed yield (kg ha⁻¹) in:										
Sahelo-Sud. zones	1200	800	1200	1200	1200	1200	1100	750	700	700
Moist savanna	-	1000	1250	1300	1300	1200	1200	1000	700	1000
Fodder yield (kg ha⁻¹)										
Sahelo-Sud. zones	1000	1000	1000	1000	1200	1200	1000	1000	1000	1500
Moist savanna	-	1200	1500	1500	1500	1500	1500	1200	1200	2000

Spr., spreading; S.E., semi-erect.

O., oval; A., acuminate; m., medium; s., small; l., large.

HR., highly resistant, R., resistant; MR., moderately resistant; S., susceptible; HS., highly susceptible; T., tolerant; ST., some tolerance.

G.A., good adaptation; F.A., fair adaptation; P. A., poor adaptation.

***Weed control*:** Where *in situ* mulch is used, chemical weed control should be practised with systemic and/or contact herbicides, such as glyphosate and Paraquat. Pre- and/or post-emergence herbicides, such as metolachlor, should also be applied. In traditional farming, two or three hoe weedings combined with scarification are done to kill weeds, destroy crusting and aerate the soil.

***Control of parasitic flowering plants*:** *Striga gesnerioides* and *Alectra vogelii* are controlled through the use of proper soil fertilization programme, cereal-cowpea rotations, and use of resistant cowpea cultivars (Table 1). Where *Striga* resistance cannot be found, *Striga* damage can be mitigated by use of *Striga* tolerant cultivars sown either in mid-July or later, for daylength sensitive cultivars (Muleba and Mosarwe, 1994), or mid-July or earlier, for daylength neutral cultivars (Cowpea Agronomy, IITA-SAFGRAD, 1983-87).

Disease control: Diseases are best controlled through the use of timely planting, proper plant population density and use of resistant cultivars; resistant cultivars have been identified and/or developed for the different agro-ecological zones (Table 1).

Insect pest control: New, improved and insect tolerant cultivars have been developed for the Sudan savanna and the Sahel (INERA, 1992-94). Yields as high as 700 kg ha^{-1} can be obtained with these new cultivars. Nevertheless, the best methods to control insect pests and achieve maximum yields is through the use of insecticides. A minimum insecticide spray regime consisting of two sprays (if there is no aphid attack) or 3 sparys (if aphid outbreak occurs towards end of the season) has been developed (Cowpea Agronomy and Entomology, IITA/SAFGRAD, 1984-87; INERA, 1988-92).

Cropping Systems

Cowpea can be grown in pure-stand, intercropping or relay cropping systems as summarized below:

Pure stand cropping system

Production practices for pure stand cropping have been described above. They are applicable to the Sahel and Sudan savanna zones. A pure stand cropping system is associated with some problems in the moist savanna. For example, daylength neutral varieties sown at the onset of the rains in late May or early June (when conditions are optimal for land preparation) mature at the peak of the rainy season (July/August) and suffer from grain mold/rot. Even though day-length sensitive cultivars sown in May/June will pod at the end of the rains, they may be attacked by foliar diseases that can severely reduce both grain and fodder yields. To avoid these problems of early sowing and those associated with mechanical land preparation under wet conditions, cowpea can be sown in mid-July using zero tillage with *in situ* mulch in moist savanna.

Intercropping system

Cereal and cowpea can be intercropped in all agro-ecological zones. Also practised are cassava or yam-cowpea intercropping systems in the moist savanna zone (Muleba and Ezumah, 1985). For maximum benefits, each component crop should be sown in alternating rows. The optimum plant population density in a row is similar to that for the pure-stand crop. The crop should be fertilized with 75-90 kg of N ha^{-1}, and 22 or 44 kg of P ha^{-1} of, respectively, soluble or rock phosphatic fertilizers. Good results, characterized by land equivalent ratios >1.0, have been obtained in semi-arid zones with cereals (maize, sorghum and millet) grown at optimum sowing dates followed two weeks later by cowpea.

Maize-cowpea relay cropping system

Under this cropping system, maize cultivars of 90 days growth duration are sown in early to mid-June, in the moist savanna zone; or in late June, in the Sudan savanna zone. Prostrate, daylength sensitive cowpea cultivars that flower in mid-September, or earlier for the Sudan savanna, are then grown underneath maize in mid-July without adverse effects on maize yield. The planting pattern and fertilizer application are similar to those of the intercropping system. Grain yields of 3 t ha^{-1} or higher for maize and 0.7-1.5 t ha^{-1} for cowpea have been consistently obtained in the Guinea savannas. Similar yields are possible for Sudan savanna during years with above average rainfall.

Mixed farming system

With the availability of capital and skilled farmers, a modern small scale (5 to 10 ha) mixed farming system can be initiated with cowpea alone or with other grains legumes, such as, soybean (*Glycine max*) and lablab (*Dolichos lablab*), as basic crops. In addition to grain legumes, the system may include cereals (maize, sorghum, millet and/or rice), root and tuber crops (for moist savanna), tree crops (fruit, fuelwood, windbreak, etc.), small ruminants and even cattle and other livestock. The rotational or sequential cropping can be terminated by three to five years of fallow, during which a mixture of grass and legume is cultivated to produce either hay or silage for livestock. Also, animal litter and manure, and tree litter and pruning may be composted to produce organic fertilizer for soil fertility restoration.

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Technology Options and Research Challenges to Increase Cowpea Production under *Striga* and Drought Stress in Semi-arid Africa.

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Abstract

Cowpea is the most important source of dietary protein in the semi-arid region of sub-Saharan Africa. It is widely grown as an intercrop in cereal-dominated cropping systems throughout West and Central African savannas. However, the productivity of cowpea is very low due to several biotic and abiotic constraints. Among the many yield-reducing factors, *Striga* and drought are the most important ones in the Sudan savanna and the Sahel. Hence, these two are major thrusts of cowpea research by international, regional and national programmes. Several options are being evaluated for the management of *Striga* and drought. Among these, the use of resistant/tolerant varieties, in combination with cultural practices, offer the most practical and economic options for the farmers. During the last few years, concerted efforts have been made by IITA, SAFGRAD, and several national programmes to develop *Striga* resistant cowpea varieties and to select varieties with drought tolerance. Good progress has been made. The details are presented in this paper.

Résuné

Le niébé est la source la plus importante de protéines alimentaires dans la région semi-aride d'Afrique Sub-Saharienne. Il est surtout exploité comme culture associée dans des systèmes culturaux à dominante céréalière à travers les savanes d'Afrique Occidentale et Centrale. Cependant, la productivité du niébé est très faible en raison de plusieurs contraintes biotiques et abiotiques. Parmi les nombreux facteurs de réduction de rendement, le Striga et la sécheresse sont les plus importants dans la savane soudanienne et au sahel, ce qui explique que les efforts de recherche sur le niébé des programmes internationaux, régionaux et nationaux portent principalement sur ces deux aspects. Plusieurs options sont en cours d'évaluation pour la lutte contre le Striga et la sécheresse. Parmi celles-ci, l'utilisation de variétés résistantes/tolérantes en combinaison avec certaines pratiques culturales, offre aux paysans les alternatives les plus pratiques et économiques. Au cours des dernières années, des efforts concertés ont été entrepris par l'IITA, le SAFGRAD et plusieurs programmes nationaux pour mettre au point des variétés de niébé résistantes au Striga et sélectionner des variétés tolérantes à la sécheresse. De grands progrès ont été accomplis dont les détails sont ici présentés.

Introduction

Cowpea (*Vigna unguiculata* (L.) Walp.) is one of the most important and versatile food legumes cultivated throughout the world. However, being drought tolerant, with better growth in warm climates, cowpea is more popular in the semi-arid and sub-humid regions of the tropics where other food legumes do not perform as well. Also, cowpea has the unique ability to fix atmospheric nitrogen, even in very poor soils, varying in pH from 4.5 to 9.0, with organic matter content below 0.2%, and sand content over 85%. These attributes, coupled with its ability to tolerate shade and quick growth for rapid ground cover, have made cowpea an essential component of various cropping systems in the marginal lands and dryer regions of the tropics. Consequently, cowpea is the most important legume crop in the semi-arid regions of sub-Saharan Africa, especially West and Central Africa where it provides both food and fodder, and maintains soil fertility.

Traditionally, cowpea is grown in mixtures with other crops, especially cereals such as millet, sorghum and, more recently, maize. Sole crop production is becoming increasingly important with the recent emergence of medium- and large-scale farmers. Small-scale farmers associated with the agricultural development projects that provide inputs (seed, spraying equipment and pesticides) have also adopted sole cropping or strip cropping that permits minimum, foliar-applied insecticide sprays.
Cowpea grain yields in Africa are low (about 100-250 kg/ha), despite the importance of the crop and farmers' sustained interest in its production. The factors associated with these low yields include erratic rainfall and associated drought, insect pests, diseases, parasitic flowering plants, and the continued use of unimproved local varieties by farmers.

Among these constraints, either drought or attack by one or both of the two parasitic flowering plants (*Striga gesnerioides* Willd. Vatke and *Alectra vogelii* Benth.) can cause up to 100% loss in grain yield in semi-arid regions of Africa. Until very recently, there were no sustainable technologies for the management of these constraints. However, given the crucial role of cowpea in semi-arid regions of Africa, SAFGRAD, in collaboration with the International Institute of Tropical Agriculture (IITA) and National Programmes, initiated a systematic research and development programme to develop cowpea varieties with drought tolerance and resistance to the above parasitic flowering plants. This paper describes the progress made so far (including an outline of available technologies to alleviate these constraints) as well as a brief discussion of the challenges that lie ahead.

Solving The *Striga* Constraint

Distribution of cowpea *Striga* and *Alectra*

Among the two parasitic seed plants, *Striga* is more prevalent in Sudano-Sahelian belt while *Alectra* is more serious in Guinean savanna. However, both are rapidly spreading beyond these limits. Thus, attack by *Striga* has been observed in the coastal savannas of Benin Republic as well as in the middle belt of Nigeria (i.e., in the southern Guinea savanna) while *Alectra* is becoming a serious threat in several East and southern African countries, particularly Kenya, Zambia, Zimbabwe, and Botswana.

Screening for resistance to cowpea *Striga* and *Alectra*

Early work on resistance to *Striga* in cowpea was carried out by IITA scientists based at Kamboinse, Burkina Faso, working under the IITA/IDRC (International Development Research Centre, Canada)/Burkina Faso and the IITA/SAFGRAD programmes. Results of this early work indicated that two varieties, "Gorom Local" from Burkina Faso and "58-57" from Senegal were resistant to *Striga* (IITA, 1982). The two varieties, together with other lines, were evaluated by IITA/SAFGRAD regional trials at many locations in Burkina Faso, Mali, Republic of Niger, Cameroon, and Nigeria during the years 1983-86 to ascertain the stability of *Striga* resistance across the West African savanna. "Gorom local" and "58-57" showed high levels of resistance to *Striga* only in Burkina Faso but were susceptible in other countries, indicating the presence of different strains (Aggarwal 1985). The subsequent search for additional sources of resistance through the collaborative work by the IITA/SAFGRAD project with Long Ashton Station, U.K. and various national programs, identified two new resistant sources in 1987, B301 (a land race from Botswana) and IT82D-849, a breeding line from IITA.

These new sources showed stable resistance to *Striga* across Burkina Faso, Mali, Republic of Niger, and Nigeria (Aggarwal, 1991; Emechebe *et al.*, 1991). In addition, a number of other lines have been identified which are apparently less susceptible, as shown by a lower number of emerged *Striga* as well as delayed emergence of *Striga* (Singh and Emechebe, 1991). Some of these lines (Table 1) display varying degrees of resistance to both parasitic seed plants. Thus, IT86D-534, IT86D-371, and IT84D-666 are moderately resistant to *Striga* and highly resistant to *Alectra*, whereas B301 is completely resistant to both. IT82D-849 is highly resistant to *Striga* but susceptible to *Alectra*. Suvita-2, which is resistant to *Striga* in Burkina Faso, is moderately susceptible to *Striga* in Nigeria but highly susceptible to *Alectra*. Among the lines highly susceptible to *Striga*, some are also susceptible to *Alectra*. These data show that significant yield reductions occurred due to the parasitic seed plants. They also indicate that breeding for *Striga* resistance alone in cowpea is not enough as *Alectra* by itself can cause severe damage, as is evident from the performance of IT82D-849 and Suvita-2. Therefore, resistance to both parasitic seed plants must be incorporated in improved varieties.

Table 1. Performance of cowpea lines in a field infested by *Striga* and *Alectra* at Kano, 1989[a].

Cowpea variety	Days to 50% *Striga* emergence	Number of parasitic seed plants/plot *Striga*	*Alectra*	Grain yield (kg/ha)
B 301	-	0	0	599
IT86D-534	66	135	1	656
IT86D-371	50	160	1	428
IT84D-666	50	92	0	410
IT84D-472	66	56	0	559
IT82D-849	-	0	63	292
SUVITA-2	46	98	110	413
IT82D-843	43	362	25	70
Vita-3	43	439	3	35
LSD-5%	11	196	20	228

[a] Two sprays of insecticide were given.

Level of resistance in different varieties

Major differences in expression of resistance in different varieties have been observed. Lack of emergence or delayed and reduced emergence are observed in resistant and moderately resistant lines, as compared with severe infection of susceptible lines. Studies in pot culture revealed that B301 roots stimulate germination of *Striga* and *Alectra* seeds and permit attachment to the roots but haustorial formation and further growth are inhibited. Lane *et al.*, (1991) reported similar observations from in vitro culture studies. On the other hand, IT82D-849 stimulates *Striga* seed germination and radicle attachment and usually inhibits haustorial development (like B301) but about 10% of the cowpea plants permit some haustorial development and support limited *Striga* growth, as well as occasional emergence of only a few *Striga* plants; these are very weak and normally die before reproductive maturity. However, IT82D-849 is highly susceptible to *Alectra*. Another variety, IT81D-994, is moderately resistant to both *Striga* and *Alectra*; it permits establishment of a few *Striga* and *Alectra* plants but delays their emergence. The emerged *Alectra* are weak and seldom reach maturity while a few *Striga* plants do reach maturity but cause little damage to the plants. The reactions of Suvita-2 to *Striga* from Burkina Faso and *Alectra* are similar to those of IT82D-849. However, it is susceptible to *Striga* from Nigeria.

Genetics of resistance

Results of studies done to elucidate genetics of resistance to *Striga* and *Alectra* in cowpea have revealed a single dominant gene for *Striga* resistance and independent duplicate dominant genes for *Alectra* resistance in B301 (Singh and Emechebe, 1990a, 1990b; Singh *et al.*, 1993; Atokple *et al.*, 1993). In addition, *Striga* resistance in IT82D-849 is controlled by a single dominant gene which is different from that of B301. Also, the single dominant gene possessed by Suvita-2 against the strain of *Stri-*

ga from Burkina Faso is non-allelic to the single dominant genes in B301 and IT82D-849. The dominant duplicate genes in B301 against *Alectra* are non-allelic to the single dominant gene in IT81D-994. Screening the parents of IT82D-849 and allelic test have revealed that its source of *Striga* resistance is Emma 60, a variety from Uganda.

Development of resistant varieties

A systematic breeding programme for resistance to *Striga* and *Alectra*, using B301 as a resistance source, was started in 1987. B301 was crossed to a susceptible variety, IT84S-2246-4, which is otherwise a high yielding variety, with resistance to aphid, bruchids, thrips and several diseases. The F_1 was backcrossed to IT84S-2246-4 and from the resistant BC_1F_1 plants F_2, F_3, F_4, F_5, and F_6 progenies were developed and selected under suitable disease, insect, and *Striga* pressures. This led to selection of a number of F6 breeding lines which are very similar to IT84S-2246-4 and have combined resistance to aphid, bruchids, thrips, *Striga* and *Alectra*, and several diseases. These were evaluated for yield and other characters in a replicated trial in the 1991-92 crop season (Table 2). The *Striga* resistant breeding lines were much superior in yield, compared with IT84S-2246-4, with mean yield improvement of 56 percent over the susceptible parent which was used as a genetic base for improvement. These lines have been distributed to various national programs in Africa and breeding continues using these lines as parents. The crossing program involves both local varieties and other selected parents in order to develop a range of varieties differing in plant type, maturity, and seed characteristics to suit different cropping systems and regional preferences. A large number of segregating populations and advanced breeding lines, involving *Striga* and *Alectra* resistance, are under test.

Table 2. Performance (grain yield, kg/ha) of *Striga* resistant cowpea varieties at different locations in Nigeria, 1991[a].

Cowpea variety	Grain yield (kg/ha) at:				*Striga* reaction[b]
	Kano	Gumel	Maiduguri	Mean	
IT90K-59-5	1289	1653	1763	1568	1
IT90K-59-3	1055	1544	1171	1257	1
IT90K-101-1	1164	1081	1117	1121	2
IT90K-102-6	1089	1657	1027	1258	2
IT90K-82-2	1104	1320	778	1067	1
IT90K-76-6	1114	1106	976	1065	1
Mean	1136	1394	1145	1223	1
IT84S-2246-4	1028	583	733	781	4
LSD 5%	337	474	475		

a Two sprays of insecticide were given

b Reactions were scored with a visual scale in which 1 = completely resistant and 5 = highly susceptible

Three of the lines have been evaluated for three years in the Nationally Co-ordinated Cowpea Project in Nigeria and the 1993 data are presented in Table 3. By the end of 1993, only one of the lines (IT90K-76) had been evaluated for three years; based on its performance it has been recommended for release in Nigeria.

Table 3. Performance of short duration cowpea varieties across 12 locations in the 1993 Nigerian Nationally Coordinated Cowpea Trial.

Cowpea Line	Cowpea grain yield (Kg/ha) at:							
	Abeokuta	Iar&t	Amakama	Nsukka	Mokwa	Badeggi	Samaru	Makurdi
1. It86d-719	603	676	1938	350	812	1172	1030	800
2. It90k-76	791	728	2250	650	582	715	817	766
3. It90k-77	647	607	2469	567	699	722	542	581
4. It84s-224	633	684	2094	317	636	896	512	498
5. It87d-941-1	634	745	2781	909	606	705	643	544
6. It90k-82-2	734	696	2575	892	725	774	1354	646
7. It90k-59	839	712	2344	375	733	927	1066	619
8. It90k-59	600	679	2938	655	618	668	776	681
9. It90k-261-3	925	784	2075	633	622	1030	712	635
Location Mean	712	701	2385	594	670	846	828	641
Std. Error	138	56	232	72	91	184	113	96
CV (%)	39	16	19	21	27	43	27	96
LSD (5%)	404	165	679	215	267	537	240	280

Table 3 Cont'd. Performance of short duration cowpea varieties across 12 locations in the 1993 Nigerian Nationally Coordinated cowpea trial.

Cowpea Line	Cowpea grain yield (kg/ha) at:					Reaction of lines to:	
	Bauchi	Maiduguri	Minjibir	Gumel	Mean	Bacterial Blight	*Striga*
1. IT86D-719	1392.47	1341.94	1791.07	951.48	1071.41	1	9
2. IT90K-76	1694.58	1008.53	1722.19	299.14	1001.97	3	0
3. IT90K-77	1663.33	577.89	936.03	216.89	752.30	3	0
4. IT84S-2246	944.52	974.08	1186.53	104.38	789.94	3	18
5. IT87D-0941-1	993.14	921.30	1212.42	216.27	909.15	3	30
6. IT90K-82-2	1441.09	410.64	1104.29	730.21		1	0
7. IT90K-101*	885.49	1160.23	1658.73	715.80		1	6
8. IT90K-59*	829.93	1276.92	1520.95	549.64		1	0
9. IT90K-261-3	1041.75	1039.10	1070.47	501.63		1	23
Location mean	1209.59	967.85	1355.85				
Std. error	354.72	171.35	209.69				
CV (%)	58.65	30.67	30.93				
LSD 5%	1037.10	514.62	613.06				

Emergence of a new *Striga* strain in Benin Republic

In 1990, a few plants of IT82D-849 and B301 were found susceptible at Zakpota, Republic of Benin. Systematic studies were then undertaken to determine whether this was due to cowpea seed mixture or to the existence of a new *Striga* strain. A number of lines known to be susceptible and resistant to cowpea *Striga* were evaluated in 1991 and 1992 at and around Zokpota and data on *Striga* infection recorded. The data on *Striga* emergence are presented in Table 4.

Table 4. Number of cowpea plants infected by *Striga* per plot in different cowpea varieties at Zakpota (Republic of Benin).

Cowpea variety	Number of *Striga* plants/plot in[a]:		
	1990	1991	1992
IT82D-849	0.5	15.5	NT
B 301	2.8	6	28
IT86D-371	32.5	25.8	NT
TVx 3236	22.8	22.3	41
IT86D-534	22.5	20	NT
IT86D-472	19.3	26.8	NT
IT84D-666	14.3	13.8	NT
IT81D-985	7.8	1.5	8
IT81D-994	0	0	0
SUVITA-2	0.8	0	1
IT90K-76	NT	NT	28
IT90K-59	NT	NT	21
IT90K-77	NT	NT	2

[a]Each plot = 6m^2; NT = not tested.

The results show that there is some level of susceptibility in B301 as well as in IT82D-849, indicating presence of a new strain of cowpea *Striga* at Zakpota. It was interesting that IT81D-994 and Suvita-2, which are resistant to the Burkina Faso strain and moderately resistant to *Striga* in Nigeria, appeared to be completely resistant to the new strain at Zakpota. Thus, it should be possible to develop cowpea varieties resistant to all known strains of *Striga* by crossing B301-derived lines with Suvita-2 or IT81D-994. This work is already in progress, along with further systematic studies on characterizing the new strain.

Long-term experiment on *Striga* control

It was postulated that because B301 and IT82D-849 stimulate *Striga* seed germination, but inhibit its development, they can be used to reduce the *Striga* seed bank in the soil. Therefore, an experiment was initiated in 1990 at Kano to study the long term effect of growing resistant varieties. There were six treatments: two resistant varieties, B301 and IT82D-849; a moderately resistant line, IT86D-472; a susceptible variety, Tvx 3236; and intercrop plot of TVx 3236 with millet, as well as a fallow plot. Each plot consists of 20 m x 15 m with 3 replications. The same variety (treatment) is planted on the plot each year with two, 2 m x 3 m windows of a susceptible variety, TVx 3236, randomly located, to estimate the density of *Striga* population in the plot. As shown in Table 5, there were no significant differences among treatments in the first two years of the trial (1990, 1991). In 1992 the numbers of emerged *Striga* in the plots where the two resistant varieties had been grown in 1990 and 1991 were significantly lower than the number that emerged in the fallow plot. The experiment will be terminated at the end of 1995 during which year the susceptible variety, TVx 3236, will be uniformly planted in all the plots and the effect of different treatments on incidence of *Striga* infection estimated. The preliminary results indicate that growing *Striga* resistant cowpea varieties will not only protect the crop itself from *Striga* attack, but will also reduce the *Striga* seed bank in the soil.

Table 5. Number of emerged *Striga* in susceptible windows (6m2) containing TVx 3236 in six treatments of different cowpea varieties or cultural treatment.

Treatment	Number of *Striga* plants/plot in[a]:		
	1990	1991	1992
Fallow	78	131	189
TVx 3236 + millet	89	46	30
TVx 3236	123	84	64
IT86D-472	166	39	56
IT82D-849	81	46	36
B 301	115	32	27
LSD-5%	NS	NS	139

Future prospects

The past and current work on host plant resistance against *Striga* and *Alectra* in cowpea suggests a good possibility of minimizing yield loss due to these parasitic weeds. In addition, their further spread can be minimized by reducing the seed bank in the soil. Evidence for strain variation in *Striga* has been noticed but, at the same time, resistance sources have also been identified for each strain and are being combined together for broad range protection. The Burkina Faso strain, as well as Zakpota strain of *Striga*, are presently restricted to a small area and only the Nigerian strain is widely distributed. However, B301 and IT82D-849 are completely resistant to both the Nigerian and Burkina Faso strains and are moderately resistant to the Zakpota strain. Thus, the *Striga* resistant varieties containing B301 or IT82D-849 genes are good enough for broad range protection. The newly identified resistant lines from germplasm screening, along with earlier resistant lines, are being tested in a range of environments to monitor emergence of new strains and their resistant sources. This will enable host plant resistance breeding to offer a broad range protection, even in the wake of new strains. Thus, the prospects for controlling *Striga* and *Alectra* on cowpea through host plant resistance are very bright.

The problem of using IT82D-849 and Suvita-2 in *Striga* resistance breeding is that both are highly susceptible to *Alectra*. This means that segregating populations of crosses involving these and B301 will need to be carefully screened for resistance to *Alectra* to ensure that the resulting lines possess combined resistance to both *Striga* and *Alectra*.

One future research cha.lenge is to combine host plant resistance with other non-chemical control measures. with a view to integrated control of cowpea-parasitic, flowering plants. Studies on macronutrients (especially N and P) have not provided much hope (Emechebe *et al.*, 1994). At present, attention is shifting to the possible role of micronutrients in boosting nodulation in cowpea, thereby helping the plant to withstand attack by the parasites.

Dealing with Drought

Screening for adaptation to drought

The SAFGRAD project, in collaboration with various national programs, evaluated a large number of varieties at different locations in the semi-arid regions, including several sites in the drier zones, in order to select varieties/parent materials for drought tolerance and specific adaptation. One of the local varieties selected from Burkina Faso, "Gorom local" performed considerably better in drier locations (IITA/SAFGRAD, 1980).

Another local varieties from the northern Nigeria - southern Niger Republic zone, "Dan lla" was found to be well adapted in the Sahelian belt between Nigeria and Niger. "Dan ila" is white seeded, while "Gorom local" is brown seeded.

Improving "Gorom Local" and "Dan lla" for pest resistance

In addition to drought stress, aphid and thrips are major problems in the Sahelian region. Since both "Gorom local" and "Dan lla" are susceptible to aphids and thrips, each of them was crossed to IT84S-2246-4, which is an improved variety with resistance to aphid, bruchid, thrips and several diseases.

The F_1 hybrid was backcrossed to the respective local varieties. From the backcross F_2 populations, individual plants were selected which looked like the local varieties but had combined resistance to aphid and thrips. These improved breeding lines have been tested at several locations and found to be very promising. The performance of a few selected lines during 1994 season is presented in Table 6. IT88D-867-11 and IT90K-109 are improved "Gorom local" while IT89KD-374-57, IT90K-372—2 and IT90K-349 are improved "Dan lla", with respect to aphid resistance as well as virus resistance. The performance of all these lines is as good as, or better than, Dan lla. IT88D-867-11 and IT89KD-374-57 have been recommended for release in northern Nigeria by the Nationally Co-ordinated Cowpea Research Project. These varieties, along with IT90K-372-1-2 and IT89KD-349, are being extensively tested in other countries and are available for on-farm trials.

Table 6. Performance of medium maturing cowpea varieties at different locations in 1994.

Variety of cowpea	Grain yield (kg/ha) at:			
	Kano	Gumel	Maradi	Niamey
IT89KD-374-57	1345	1451	1315	1224
IT90K-372-1-2	1420	1284	1085	2577
IT88D-867-11	1100	1315	1240	1685
IT90K-365	1888	793	1219	1644
IT90K-109	1274	1545	697	888
Dan lla	939	188	1670	-
IT89KD-349	1432	250	1014	1481
CV (%)	23	34	21	47
LSD, 5%	425	459	306	930

Breeding for drought tolerance

With the establishment of IITA Kano Station, and the subsequent collaborative research with Japan International Research Centre for Agricultural Sciences (JIRCAS), research work on breeding for drought tolerance has received greater thrust, and good progress has already been made. Screening of over 900 germplasm lines has resulted in the identification of good sources of drought tolerance. Some of these are TVU 11979, TVU 11986, TVU 12349, Dan lla, and IT90K-59-2.

These lines have been crossed to selected parents, both for genetic studies as well as to develop breeding populations. It is expected that within three years, improved cowpea varieties with high levels of drought tolerance will be available.

Conclusions

. Good sources of resistance to *Striga* and *Alectra* in cowpea have been identified.
. Good sources of drought tolerance in cowpea have also been found.
. A number of varieties have already been developed which combine resistance to aphid, thrips, *Striga*, and *Alectra* with good adaptation to drier regions. Already one of these lines has been recommended for release in Nigeria.
. Concerted efforts are being made to incorporate higher levels of drought tolerance in improved cowpea varieties.

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Performance en Milieu Paysan des Technologies Améliorées pour Accroître la Production du Niébé Grain au Niger

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Résumé

Deux variétés améliorées de niébé TN 28-87 (cycle intermédiaire), et KVX 30-309-6G (précoce) ont montré une adaptabilité générale et une bonne stabilité de rendements grain en essais multilocaux conduits en hivernage 1993 et 1994 dans plusieurs environnements sahéliens et nord-soudaniens du Niger.

La combinaison de TN28-87 aux techniques culturales améliorées dans des tests de prévulgarisation conduits en hivernage 1994 dans 30 villages, a permis d'augmenter de 63% le rendement grain moyen. Le simple changement variétal (la variété améliorée TN 28-87 à la place de la variété locale) dans le système de cultures du paysan (semis à grands écartements avec plusieurs plants par poquet, sans fumure ni protection chimique contre les insectes) a entraîné un gain relatif de 61 % du rendement grain moyen.

Abstract

Two improved cowpea varieties (TN28-82 (medium cycle) and KVx 30-309-6 G (Short cycle) showed general adaptability and good grain yield stability in multilocational trials conducted during the 1993 and 1994 cropping seasons in several sahel and North-Sudan environments in Niger

Combining TN28-87 with improved cropping techniques in pre-extension trials conducted during the 1994 cropping season in 30 villages increased the mean grain yield by 63%. The simple variety change (improved variety TN28-87 instead of the local variety) in the farmer's cropping system (widely spaced planting with several plants per hill without fertilization nor chemical insect control) resulted in a relative 61% increase in mean grain yield.

Introduction

Première légumineuse alimentaire, le niébé est la deuxième culture (en superficie) au Niger après le mil. Il est essentiellement cultivé en association avec les céréales (mil notamment) pour les graines et dans une moindre mesure pour le fourrage à proximité de certains centres urbains. La production nationale est estimée à 430.000 tonnes en 1991 (MAG/EL, 1993). Cependant, le rendement grain moyen national est en baisse générale : 230 kg/ha pour la période 1972-1981 contre 137 kg/ha pour la période 1982-1991 soit une diminution de 40% entre les deux décennies (MA/EL, & 1993).

Le parasitisme, l'inadaptation des variétés locales, l'insuffisance d'information sur les technologies améliorées et la non disponibilité de celles-ci en temps et lieux indiqués comptent parmi les principales contraintes à la production du niébé grain au Niger. L'inadaptation variétale est principalement liée à la photosensibilité et à l'architecture (port généralement très rampant) des cultivars locaux, deux caractères manifestement non-favorables pour des objectifs de production de grain dans un contexte agro-climatique marqué par la prédominance des cultures associées et une saison des cultures ne dépassant guère 90 jours (ICRISAT-SC, 1989). Les génotypes à cycle précoce ou intermédiaire (70-80 jours semi-maturité), à port semi-rampant semblent plus adaptés à la production de grain en culture associée mil-niébé (Reddy *et al.*, 1990; N'TARE, 1989).

La sélection en culture pure des variétés de niébé destinées principalement à la production de grain en culture pure ou associée mil-niébé se justifie par l'existence d'une corrélation positive et significative entre les rendements grains de niébé dans les deux systèmes culturaux (N'TARE; 1989).

Depuis sa création, l'Institut National de la Recherche Agronomique du Niger (INRAN) à travers un programme pluridisciplinaire d'amélioration de la culture du niébé s'efforce de lever ou tout au moins minimiser les contraintes à la production du niébé par la mise au point et à la disposition des paysans des variétés adaptées à la production de grain et/ou fourrage dans les principaux systèmes de cultures.
La présente communication porte essentiellement sur des activités menées en 1993 et 1994 en milieu paysan en vue de tester la stabilité et l'adaptabilité de nouvelles variétés de niébé au Niger.

Matériels et Méthodes

Essai 1

Le but de l'essai était de tester l'adaptabilité et la stabilité de 3 nouvelles variétés; d'en familiariser les vulgarisateurs et les paysans et recevoir le feed-back de ces derniers en vue de permettre un meilleur ajustement des technologies, si besoin était.

Cinq (5) variétés (Tableaux 1) dont un témoin de productivité (TP) largement vulgarisé au Niger et un témoin local (TL) ont été testés pendant deux années (1993 et 1994) dans 35 champs-paysans, situés chacun dans un village environnant des stations et points d'appui de la recherche (annexe 1). Cette approche est motivée par le souci d'un meilleur suivi des essais en milieu paysan. Le témoin local, variable d'un site à l'autre, est un cultivar local ou amélioré largement cultivé par les paysans de la zone.

Tableau 1. Caractéristiques des variétés utilisées.

Variétés	Origine	cycle (jours)	Couleur des graines	Taille des
KC85-7	INRAN/NIGER	75	Crème	Moyenne
KVX30-309-6G	UTA/BURKINA	70-75	Blanche	Grosse
TN5-87 (TP)	CLA/NIGER	75-80	Blanche	Moyenne
TN28-87	CLA/NIGER	70-75	Brune	Moyenne

ClA: Cultivar local amélioré, TP: témoin de productivité

Le dispositif expérimental est en blocs complets randomisés avec deux répétitions. La parcelle élémentaire est constituée de 4 lignes de niébé pur semé sur une longueur de 6,40 m. La parcelle utile est constituée des 2 lignes centrales soit une superficie récoltée 10,88 m^2.

Conformément aux recommandations de la Recherche, seul un apport de 18 kg de P_2O_5 a été fait à la préparation du sol (labour léger ou scarifiage). Les semis sont effectués du 4 juillet et 2 août (dont plus de 97% en juillet) aux écartements de 0,80m et 0,40m respectivement entre les lignes et les poquets; ce qui donne une densité théorique de 63000 plants/ha.

Deux (2) traitements chimiques au Karaté EC (1l/ha), Karité ULV (2,5 l/ha) Karaté ED (0,5 l/ha), Dimethoate EC (1 l/ha), ou au Fenitrothion (0,5 l/ha) ont été assurés à la phase formation des boutons floraux-floraison-formation des gousses. Le choix de l'insecticide est laissé au soin de l'Agent vulgarisateur selon les disponibilités locales, dans la gamme des produits recommandés.

Les observations ont porté essentiellement sur la date de floraison moyenne, le poids des gousses et des graines, le parasitisme. Le feed-back s'appuie sur le choix successif (premier àcinquième) que le paysan fait dans les variétés selon ses propres critères.

Les analyses de variance portant uniquement sur les rendements grains ont été faites avec le logiciel Statistical Analysis System (SAS). L'analyse multilocale et pluriannuelle est faite selon le modèle mixte où l'année et les localités sont considérés aléatoires et les variétés fixes (M.S.Mcintosh, 1983). La stabilité de rendement est appréciée par l'analyse de l'interaction génotypes-environnements et l'analyse de regression du rendement individuel des variétés sur les rendements moyens de toutes les variétés au niveau des sites (Finlay et Wilkinson, 1963, rapporté par plusieurs auteurs).

Essai 2

Le but était de vérifier l'adaptabilité de la variété TN28-87 en milieu paysan et en recueillir le feed-back des utilisateurs.

Quatre traitements ont été testés:

T1 = Système amélioré (variété et techniques améliorées: TN 28-87, apport de 18 kg/ha P_2O_5, densité de 63000 plants/ha, 2 applications d'insecticide pendant la phase formation des boutons floraux-formation des gousses, deux sarclages: voir essai 1)

T2 = Variété locale + techniques améliorées (voir T1)

T3 = Variété améliorée + techniques traditionnelles (densité de semis libre, en général pas de fumure phosphatée ou de traitements chimiques)

T4 = Système traditionnel (variété locale + techniques traditionnelles : voir T3).

En système amélioré, les semis se sont échelonnés du 02 juillet au 12 août, et du 14 juin au 12 août. Pour le système traditionnel (les paysans ont tendance à semer plus tôt si les conditions le permettent). L'essai est conduit dans 39 champs paysans (annexe 1), chacun constituant une répétition. La parcelle utilisée est de 144 m². Les observations ont porté sur les poids des gousses et des grains, la floraison moyenne et le parasitisme. La réaction des paysans est reçue à travers un questionnaire ouvert (questions non spécifiques) lui demandant son appréciation globale ou particulière sur les technologies proposées. L'analyse de variance du rendement grain est faite selon le dispositif en blocs complets randomisés.

Résultats

Essai 1

Vingt quatre (24) protocoles ont été analysés en 1993 contre vingt trois (23) en 1994. L'analyse combinée a porté sur 16 sites communs aux deux années. Le tableau 2 et 3 montrent respectivement les résultats de l'analyse de variance et les rendements grain et les coefficients de regression b mesurant la stabilité de rendement des variétés.

Tableau 2. Analyses des variances du rendement grain.

Sources de variation	1993	1994	1993-1994
Génotypes	4.5**	4.3**	7.5**
Environnements	47 **	20 **	43 **
Années	-	-	2.2ns
Génotypes x environnement	1.7**	0.7ns	0.9ns
Génotypes x années	-	-	0.7ns
Génotypes x années x environne-	-	-	1.1ns

** : F significatif à 1%
ns : F significatif à 5%.

Tableau 3. Rendements grains (kg/ha) et coefficients b.

Variétés	1993 en % TL		1994 en % TL		1993-94 en % TL		b
1. TN 28-87	1164 a	128	1249 a	137	1266 a	134	1.02
2. KVX30-309-6G	1095 ab	120	1102 ab	121	1138 ab	121	1.06
3. KC85-7	979 bc	112	1025 bc	112	1037 bc	110	0.91
4. TN5-78 (TP)	1155 a	127	1196 a	131	1204 a	128	1.00
5. Locale (TL)	911 c	100	913 c	100	941 c	100	
Moyenne	1061		1097		1117		
C.V. (%)	33		35		33		
PPDS (5%)	142		162		133		

N.B. Les moyennes suivies par la même lettre ne sont pas significativement différentes à a.0.5.

L'appréciation individuelle des variétés par les paysans s'est révélée difficile, compte tenu du nombre relativement élevé des variétés (5). Toutefois, les critères les plus invoqués sont la production des gousses, la précocité, la blancheur des graines, la couverture du sol, etc...

Essai 2

Le tableau 4 montre les résultats de l'analyse de variance du rendement grain sur 30 sites (30 protocoles exploités).

Tableau 4 . Rendement grain en kg/ha.

Traitement	Rendement grain	En % T4	En % (T3+T4)
T1	811 a	270	
T2	497 b	165	167
T3	483 b	161	
T4	300 c	100	100
Moyenne	524		
C.V.(%)	60		
PPDS (5%)	165		

N.B. Les moyennes avec la même lettre ne sont pas significativement différentes à a=0.05.

Contrairement à l'Essai 1, l'appréciation des paysans a dans ce cas été plus facile, étant donné le nombre plus réduit des variétés (2), la simplicité du dispositif en quatre parcelles visualisant très aisement les différences entre les traitements.

Discussions

Essai 1

Les analyses de variance (Tableau 2) montrent des effets génotypes et environnements hautement significatifs en 1993, 1994 et dans l'analyse combiné. Quant à l'intéraction génotypes x environnements elle n'est significative qu'en 1993. L'absence d'intégration génotypes x environnements dans l'analyse combinée signifie que les différences de rendement grain entre les variétés ne sont pas significativement influencées par l'environnement, autrement dit le classement des variétés selon le rendement est indépendant de la localité.

L'analyse de regression (en fait non indispensable étant donné l'absence d'interaction) du rendement des variétés sur le rendement moyen des variétés au niveau des sites réalisée sur les 47 localités (24 en 1993 et 23 en 1994) montre des coefficients b proches de 1; cela tend donc à confirmer la bonne stabilité des 3 nouvelles variétés au sens de Finlay et Wilkinson cité par M.Jacquot, 1974; C.S.Lin et al., 1986; N.W. Simmond, 1988; N.Muleba et al., 1991.

TN28-87 et KVX30-6G ont montré la meilleure adaptabilité au sens des mêmes auteurs en permettant des gains de rendement grain respectifs de 34 % et 21 % par rapport au témoin moyen local. Cependant, seule la TN28-87 a permis un gain de rendement grain de 5 % par rapport à la TN5-78 (TP). Par ailleurs, le jugement des paysans tendait globalement en faveur des deux variétés pour les critères ci-dessus indiqués.

Essai 2

L'analyse du tableau 3 montre que :

- l'application des thèmes techniques (T1+T2 opposé à T3+T4) a permis d'accroître le rendement grain de 67 %.
- l'application du traitement T1 (paquet technologique complet) à la place de T4 (témoin du paysan) permet de multiplier la production de grain par 2,7.
- L'unique changement variétal (utilisation de la variété améliorée à la place de la variété locale c'est-à-dire T3 au lieu de T4) permet un accroissement de la production de grain de 61 %.

Cette analyse rejoint l'appréciation très positive que les paysans ont des engrais minéraux, et surtout des traitements chimiques contre les insectes. La très bonne appréciation par les paysans de la variété TN28-87 pour la production des gousses et le cycle (comparativement à beaucoup de variétés locales tardives), la blancheur des graines et la couverture du sol donne l'espoir de combler enfin un vide dans la gamme des variétés recommandées à la vulgarisation par la recherche. Par contre, la densité de semis en pure préconisée par la recherche a été globalement jugée trop forte et techniquement difficile à mettre en oeuvre par les paysans. Ces appréciations nous ont paru d'autant plus fondées que les sols sont en général sableux, pauvres en matière organique et en phosphate, avec une faible capacité de retention en eau d'une part et la capacité d'investissement par les paysans (achat d'intrants) relativement faible, d'autre part.

Conclusions

Les deux essais conduits en milieu paysan ont montré l'adaptabilité et la stabilité de rendement des variétés TN28-87 et KVX30-309-6G, bien appréciées par les paysans pour le cycle, la production des gousses, la blancheur des graines et la grosseur des graines (surtout pour KVX30-309-6G). L'utilisation de ces variétés améliorées à la place des variétés locales permettrait une amélioration substantielle des rendements grain et ceci indépendamment du niveau de technique du paysan.

Les deux variétés ont été proposées à la vulgarisation sous la dénommination respective de 'Dan Bagazan' (allusion au Mont Bagazan, montagne célèbre de l'Aïr au Niger) et 'Dan Bobo' (allusion à Bobo-Dioulasso, ville du Burkina Faso, où la variété qui a été sélectionnée, est par la suite devenue très populaire au Niger).

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Potential of Dry Season Cowpea in West Africa

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Abstract

Cowpea (*Vigna unguiculata* (L.) Walp.) is a major food legume in West Africa. It is primarily grown in mixture with sorghum, millet, maize, etc. during the rainy season. However, due to low plant density, shading by cereal crops and lack of crop protection measures, as well as other production constraints, the average yield of cowpea is low. With the rapid increase in population, the per capita availability of cowpea is further declining, causing wide spread protein malnutrition in the rural as well as urban areas. Recent studies have revealed a great potential of pure crop cowpea cultivation during the dry season in fadamas and other wet lands on residual moisture as well as in irrigated areas as a rotation crop in rice-wheat system. It also fits well as a substitute crop for wheat, in case wheat planting is not possible due to late harvest of the preceding crop. Cowpea can be planted from November to February 15, depending upon the location and moisture level, and harvested well before the next rainy season. Due to low insect pressure and availability of aphid and thrips resistant varieties, grain yields up to 2 tons/ha and dry fodder up to 5 tons/ha have been obtained. Since West Africa has several million hectares of fadamas and wet lands, there is good potential for increasing cowpea production in the dry season.

Résumé

Le niébé, *Vigna unguiculata* (L) Walp est une importante légumineuse vivrière en Afrique Occidentale. Il est essentiellement cultivé en association avec le sorgho, le mil, le maïs etc. au cours de la saison des pluies. Cependant, compte tenu de la faible densité de plants, de l'ombrage des céréales et de l'absence de mesures de protection ainsi que d'autres facteurs, la moyenne de rendement du niébé est faible. Avec l'accroissement démographique rapide, la disponibilité du niébé per capita se réduit davantage, provoquant une malnutrition protéique généralisée dans les zones rurales aussi bien qu'urbaines. Des études récentes ont révélé un grand potentiel de la culture pure du niébé en saison sèche dans les fadamas et autres terres humides grâce à l'humidité résiduelle ainsi que dans les zones irriguées comme culture de rotation dans un système riz-blé. Le niébé convient bien également comme culture de substitution au blé lorsque le semis du blé n'est pas possible à cause de la récolte tardive de la culture précédente. Le niébé peut être semé de Novembre jusqu'au 15 Février selon la localité et le niveau d'humidité et être récolté avant la saison pluvieuse suivante. Du fait de la fiable pression des insectes et de la disponibilité de variétés résistantes au aphidés et aux thrips, des rendements en grain allant jusqu'à 2 tonnes/ha et du fourrage sec de près de 5 tonnes/ha ont été obtenus. Dans la mesure où l'Afrique Occidentale a plusieurs millions d'hectares de fadamas et des terres humides, il existe de bonnes potentialités d'accroître la production du niébé en saison sèche.

Introduction

Cowpea (*Vigna unguiculata* (L.) Walp.) is the major source of dietary protein in many countries of sub-Saharan Africa, especially among the rural and urban poor. It is widely cultivated in the West African savannas in the rainy season (June-October) in mixture with maize, sorghum, and millet as an integral component of the prevalent cropping systems and provides food as well as fodder. However, due to competition with cereals and inadequate crop protection measures, the average yield of cowpea is very low. With the high rate of population growth in Africa, the demand for cowpea increases yearly, resulting into higher prices and low availability to poorer people. Therefore, concerted efforts need to be made to increase cowpea production in the rainy season as well as in the dry season (November-May) using inland valleys (fadamas) on residual moisture and with irrigation, wherever possible.

The total area of inland valley swamps in West Africa is estimated to be between 10.1 to 21.8 million hectares (Hekstra *et al.*, 1983). Inland valleys are further characterized by shallow water tables, even during the dry season, ranging from 0 to 1.5 m deep below the soil surface (Hekstra *et al.*, 1983, Smaling *et al.*, 1985, Van Vuure and Mledemo 1973, Hulugalle and Lal 1985). Dry season cropping is, therefore, possible and the most common crops grown are vegetables, cowpea, cassava, sweetpotato and sugarcane (Palada *et al.*, 1987, Ashraf *et al.*, 1988). Also, several West African countries have developed large irrigated areas. Normally, rice is grown in the fadam and irrigated areas during the rainy season and a range of crops during the dry season depending upon the residual moisture. Some countries are popularizing wheat cultivation during the dry season where assured irrigation is available and temperatures are lower. However, cowpea fits very well as a rotation/alternate crop during the dry season as it requires less water and matures within 60-90 days. This paper summaries the work done on the prospects of cowpea cultivation during the dry season.

Early Cowpeas in Rice Fallows

Rice is widely grown in fadamas of West and Central Africa. It has been observed that after rice harvest, enough residual moisture remains in the field for up to 40-50 days, to permit cultivation of an early maturing crop. With the development of 60-day cowpeas by IITA in early 1980s (Singh, 1982), several cowpea variety trials were conducted at Ibadan and Bida (Nigeria) in rice fallows. The results revealed that, if after rice harvest, the soil surface was moist enough to permit planting and germination of cowpea seeds, then there would be enough moisture in the soil for a cowpea crop. The cowpea roots followed the receding water table and enabled the plants to complete vegetative and reproductive growths before water level went too far down. The results of 1983-84 trials are presented in Tables 1 and 2 which indicate that short duration cowpea varieties can yield 1.0-1.5 t/ha within 60-65 days after planting. Based on these results, the scientists of Resource and Crop Management Division (RCMD) of IITA conducted several on-farm trials in rice fallows of the Bida Area. They obtained up to 1 ton/ha grain yield of cowpea on farmers fields planted after rice on residual moisture. Farmers in Bida area had never imagined that they could grow anything after rice. Most of these farmers' have large families and they are usually busy only for 4 months of the year, i.e., during the rainy season. The cowpea crop in rice fallows offered an opportunity for gainful employment to the family members, as well as nutritious food and higher income from the same piece of land (Singh, 1986; Palada *et al.*, 1987; Ashraf *et al.*, 1988). In similar trials at Makeni, Sierra Leone, in the dry season of 1987, several early cowpea varieties yielded over 800 kg/ha within 65-68 days.

Table 1. Performance of 60-day cowpea varieties in rice fallow at Ibadan, Nigeria, 1983-84.

Cowpea variety	Days to maturity	Yield (kg/ha)*
IT82E-9	62	1019
IT82E-18	66	1294
IT82E-60	63	1342
IT82ED-889	60	1136
IT83D-789	64	1139
IT82D-948	65	823
IT82D-890	62	997
Ife Brown	70	814
LSD 5%	1.6	333

* Planted 21-12-83.

Table 2. Performance of cowpea varieties in wet and dry transects of rice fallow at Ibadan, Nigeria, 1984-85*.

Cowpea variety	Days to maturity			Yield (kg/ha)			Harvest Index (%)
	Dry Transect	Wet Transect	Mean	Dry Transect	Wet Transect	Mean	
IT83D-442	52	56	54	1428	1570	1499	46
IT82E-9	56	61	59	1184	1549	1367	52
IT82D-889	52	56	54	1060	1341	1201	50
IT82E-124	56	60	58	914	1368	1143	47
IT82E-60	56	61	59	901	1043	972	51
LSD 5%	1.0	0.7		327	231		9

* Planted Nov. 30, 1984.

Early Cowpeas in Northern Wet Lands and Irrigated Areas

The Hadejia-Jama'are flood plain, including Nguru wet land, covers approximately 3500 km² situated in the north-eastern Sahel zone of Nigeria between latitude 12°-13°N and longitude 10°-11° East. It is part of the Hadejia-Jama'are-Yobe river basin and is formed by these rivers branching and dividing over a relatively flat alluvial plain, as they drain north east across an area of arid Sahel savanna towards Lake Chad (Amans *et al.*, 1992). Only the non-flooded areas are cultivated in the rainy season but during the dry season most of the area is cultivated when water recedes, except for a few pockets which remain flooded. With recent introduction of shallow borewells, even the upper part of the flood plain (where water table is not too deep) is being used for cropping during the dry season (Tukur, 1995). Also, when Lake Chad recedes during the dry season, large areas around the banks of the lake become available for dry season cropping, for which cowpea is one of the popular crops. Several northern states in Nigeria have developed irrigation projects where wheat is planted during the dry season. However, due to late harvesting of the previous crops like rice and sorghum, wheat planting is sometimes delayed. The normal time of planting wheat is from first week of November to first week of December but some farmers plant up to the end of January; yield of such crops are very low, due to high temperatures in March-April. In such cases, cowpea cultivation is highly profitable.

The major constraints during the dry season are viruses, leaf thrips, nematodes and aphids. The International Institute of Tropical Agriculture (IITA) has developed several cowpea varieties with combined resistance to viruses, thrips, nematodes, aphids, bruchid, *Striga*, etc. Therefore, a number of these varieties were evaluated at Wudil and Kadawa with irrigation and in Nguru wetland area with farmers participation from 1991 to 1994 (Singh, 1993; Blade and Singh, 1994). The grain yields of selected varieties at Wudil and Kadawa under irrigation are presented in Table 3. These data indicate that varieties with combined resistance to thrips, aphid, nematodes and viruses yielded 1 ton to 1.5 ton/ha when planted at the end of January. At the time of harvesting (end of April) prices of both grain and fodder are very high. A few selected varieties were again tested in 1993 and 1994 and the data on grain and fodder yields are presented in Table 4. Grain yields of over 1 ton/ha and fodder yields of between 4 to 10 tons/ha were obtained. The improved varieties out-yielded the local varieties.

Table 3. Mean grain yield (kg/ha) of some cowpea varieties at different planting dates in dry season at Wudil and Kadawa (Nigeria).

Cowpea variety	Grain yield at Wudil on:			Grain yield at Kadawa on 31/1/92	Reaction to*				
	19/1/91	31/1/91	31/1/92		Ap	Br	Tr	St	Nt
IT86D-715	405	1104	-	-	S	S	R	S	S
IAR-48	573	1042	-	-	S	S	S	S	S
Local (Dan Ila)	1524	1119	398	851	S	S	S	S	S
IT84S-2246-4	1524	1980	1148	1638	R	R	R	R	R
IT86D-719	1146	1269	-	-	MR	S	R	S	R
IT90K-76	-	-	1776	1570	R	R	R	R	R
IT90K-59	-	-	1518	1148	R	R	R	R	R
IT90K-101	-	-	1033	1705	R	R	R	R	R
IT89KD-288	-	-	-	1087	R	R	R	R	R
IT89KD-374	-	-	711	1104	R	S	R	MR	S
LSD 5%	693	682	371	491					
CV %	24	19	27	29					

* Ap = Aphid, Br = Bruchid, Tr = Thrips, St = *Striga*, Nt = Nematode.

Table 4. Grain and fodder yield of cowpea varieties in the dry season at Kadawa (Nigeria).

Cowpea variety	1993 yields		1994 yields	
	Grain (kg/ha)	Fodder (t/ha)	Grain (kg/ha)	Fodder (t/ha)
IT87D-941-1	1773	4.1	1206	10.8
IT84S-2246-4	1293	6.5	925	9.9
IT90K-76	-		1009	9.2
Local check (Dan Ila)	1495	1.9	333	4.1
LSD (5%)	ns	1.5	443	2.9

Four improved varieties were also evaluated at Nguru on the receding wet lands using the residual moisture only. The yields are presented in Table 5. The yields were relatively low due to poor plant population but the improved varieties were again significantly better than the local checks.

Table 5. Grain yield of cowpea varieties without insecticide protection at the Nguru wetlands (Nigeria), 1994.

Cowpea variety	**Grain yield (kg/ha)**
IT84S-2246-4	641.5
IT89KD-319	402.3
IT89KD-288	307.0
IT89KD-941-1	285.6
Local check	113.4
LSD (5%)	233.4

On-farm evaluation of selected varieties using farmer participatory approach in Nguru area and at three Kano State sites (Minjibir, Wudil, Kadawa) have confirmed on-station trial results and farmers are enthusiastically adopting cultivation of improved cowpea varieties in the dry season. From 200 g seeds of IT89KD-288 we gave to one farmer in 1992, he has been able to multiply and arrange planting of 20 acres under this variety in 1995 involving 20 farmers of his village, Bunkure (Kano State, Nigeria). For various reasons, these fields could not be planted with wheat. Farmers are extremely happy and excited to see the excellent cowpea crop in the dry season which was harvested by end of April, 1995. Several hundreds farmers have already booked the seeds for the next season. The Fulani cattle herders have also approached the farmers for purchase of cowpea haulms from these fields so that they do not have to travel down south with their herds in search of grazing grounds.

Conclusions

(i) The results from evaluation of cowpea varieties in the dry season at different locations have demonstrated good potential for increasing total cowpea production in several African countries where residual moisture or irrigation facilities exist.

(ii) Improved cowpea varieties (with high yield potential in the dry season) combining resistance to aphid, thrips, bruchid, nematode, viruses and *Striga* have been developed. Also, some of the photosensitive varieties like IT89KD-288 and IT89KD-374 which are late maturing in the rainy season due to longer day length, are very early in the dry season due to shorter days.

(iii) On-station and on-farm trials have shown that selection of varieties and date of planting are critical for high grain and fodder yields in the dry season, particularly in northern locations.

(iv) Dry season cowpea will contribute to system sustainability due to atmospheric nitrogen fixation, soil improvement and less input requirements. It also implies efficient use of land, labour and other farm resources which are normally idle during this period.

(v) The produce from dry season cowpea - both grain and fodder - come during the "hunger period" and therefore, will fetch higher prices for the farmers while at the same time reducing consumer prices.

(vi) Growing dry season cowpea reduces the need for long term storage of the produce and thus, minimizes storage losses.

The authors strongly recommend that researchers and extension workers promote this technology. (Seeds of improved varieties will be made available on request.)

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On-Farm Testing of Variety and NPK Fertilization for Maize/ Cowpea Mixture in the Nigerian Savanna

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Abstract

Maize/cowpea mixture is one of the important crop mixtures in the farming systems of the Nigerian savanna. Improvement of crop production in this zone depends on amelioration of the inherent low soil fertility and adoption of high-yielding, improved varieties. On-farm trials were conducted in two villages in the Sudan savanna zone and one village in the northern Guinea savanna ecological zone of Nigeria from 1992-94 to evaluate maize and cowpea varieties and NPK fertilization for the maize/cowpea mixture. Thirty two farmers were involved in the study in 1992, 33 in 1993 and 48 in 1994. The application of 120 kg N, 26 kg P and 50 kg K/per ha resulted into higher maize and cowpea grain yields compared with half of this fertilizer rate. Improved maize variety, TZBSR-W, and cowpea variety, SAMPEA-7, consistently outyielded the local varieties. Using improved varieties of maize and cowpea increased net income by as much as 87% compared with the farmers' varieties. Net returns per hectare from using 120 kg N, 26 kg P and 50 kg K per ha were also 45-57% higher than half of this fertilizer dose. The results suggest that the technology could be of great financial benefit to the small-scale farmers.

Résumé

L'association maïs/niébé est l'une des principales associations de cultures des systèmes culturaux de la savane du Nigéria. Dans cette zone, l'amélioration de la production agricole dépend de l'amélioration de la fertilité des sols qui est naturellement faible et de l'adoption de variétés améliorées de haut rendement. Des essais en milieu paysan ont été conduits dans deux villages de la zone Soudanienne et dans un village de la zone écologique de savane Nord guinéenne du Nigéria de 1992 à 1994 afin d'évaluer des variétés et la fertilisation par NPK dans l'association maïs/niébé. Cinquante cinq paysans ont été associés à ces essais dans les trois localités. L'application de 120 kg de N, de 26 kg de P et de 50 kg de K/ha a entraîné une augmentation des rendements en grain du maïs et du niébé ainsi qu'une marge brute supérieure par rapport à l'application de la moitié de cette dose d'engrais. La variété de maïs améliorée TZBSR et la variété de niébé SAMPEA-7 ont constamment donné des rendements supérieurs àceux des variétés locales. Avec des variétés améliorées de maïs et de niébé, la marge brute augmentait d'environ 87 % par rapport aux variétés locales. Indépendamment des localités, tous les paysans aimeraient adopter la variété améliorée de niébé SAMPEA-7.

Introduction

Over 90% of the estimated 1.8 metric tonnes of cowpea (*Vigna unguiculata* (L.) Walp.) produced in Nigeria is cultivated in the savanna agroecological zones, notably in the northern Guinea and Sudan zones which together account for about 75% of the total production. These two zones cover an area of about 400,000 km^2 within latitudes 10 and 13° North and longitudes 4 and 14° East (Kowal and Knabe, 1972).

The bulk of cowpea production comes from fields of small-scale farmers under intercropping with cereals, particularly millet and sorghum. Recently, however, maize is becoming increasingly popular in the Nigerian savanna where maize/cowpea mixture is one of the common maize-based cropping systems.

Average yield of maize in the savanna is much higher than that in the forest zone (Fajemisin, 1992). However, the use of a high level of inorganic fertilizer is a prerequisite to the achievement of this high yield potential, since savanna soils are inherently low in native fertility, particularly nitrogen and phosphorus (Heathcote and Stockinger, 1970; Mokwunye, 1979). These soils which are predominantly Entisols, Alfisols and Inceptisols are also characteristically low in organic matter and CEC and are largely coarse textured. Despite the fact that the production of maize is economical only when nitrogen fertilizers are applied in combination with those of phosphorus and potassium, fertilizer use per hectare in Nigeria is still very low (Uyovbisere and Lombin, 1991) mainly because of fertilizer scarcity and its soaring cost.

Being a relatively new crop, nearly all farmers in the savanna zone grow improved maize varieties. However, most farmers are yet to adopt the cultivation of improved cowpea varieties. Studies on-station have shown wide variations in the yields of cowpea varieties while results of on-farm tests have revealed that some of the improved cowpea varieties are not as productive as the farmers' varieties under the traditional cropping systems (Elemo, 1993). Since the improvement of maize/cowpea cropping system depends on amelioration of the inherent low soil fertility and adoption of improved varieties, the present study was conducted to: (a) evaluate the performance of improved varieties of maize and cowpea as compared to farmers' varieties; (b) evaluate the financial costs and benefits of the use of improved varieties and fertilizer practice, and (c) enhance the process of adoption of improved varieties of cowpea and maize as well as fertilizer practice.

Methodology

The study was undertaken at Daudawa and Malumfashi villages in Katsina State and at Makarfi in Kaduna State of Nigeria during the wet seasons of 1992 to 1994. Daudawa and Malumfashi fall within the transitional zone between Sudan and northern Guinea savanna while Makarfi is in the northern Guinea savanna. The description of the locations is given in Table 1 while Table 2 presents some properties of the surface soils of the experimental sites.

Table 1. Parent material and soil classification of experimental sites.

Site	Latitude	Soil grouping parent material	USADA/FAO soil classification
Malumfashi	11'47'N	Less leached shallow soils overlying basement complex rocks.	Haplustalf/Luvisol
Daudawa	11'31'N	Shallow soils on acid crystalline rocks.	Haplustalf/Luvisol
Makarfi	11'20'N	Shallow soils on acid crystalline rocks.	Haplustalf/Luvisol

Table 2. Physico-chemical properties of surface soils (0-15 cm) of the experimental sites.

Soil property	Daudawa	Malumbashi
pH (H_20)	5.0-5.4	4.4-5.2
pH ($CaCl_2$)	4.9-5.1	4.0-5.0
Organic carbon (%)	0.14-0.26	0.20-0.30
Bray P- (mg/kg)	5.37-8.96	7.17-9.96
Exch. K (meq/100g)	0.04-0.07	0.03-0.07
Exch. Ca (meq/100g)	2.04-2.31	1.84-2.24
Exch. Mg (meq/100g)	0.82-2.31	0.63-1.12
Exch. Na (meq/100g)	0.01-0.02	0.01-0.09
CEC (meq/100g)	3.90-4.60	3.40-4.50
% N	0.07-0.18	0.40-0.08
Textural class	Sandy Loam	Sandy Loam

Trials were conducted at Daudawa in each of the three years of the study while work was not done at Malumfashi in 1993 because of logistic problems. The study was undertaken at Makarfi in 1993 and 1994 only. Twelve farmers participated in the study at Daudawa in each of the wet seasons of 1992 and 1994 while there were 13 participants in 1993. At Malumfashi, there were 30 participants in each of the wet seasons of 1992 and 1994. At Makarfi, on the other hand, there were 20 and 16 participants in the wet seasons of 1993 and 1994, respectively.

An area of 0.2 ha was measured out of each participating farmer's field and this was further divided into four (i.e., 0.05 ha each) to which the following four treatments were randomly allocated:

1) Improved maize variety, TZBSR-W, and cowpea variety, SAMPEA-7, + 60 kg N, 13 kg P and 25 kg K per ha.

2) Improved maize variety, TZBSR-W, and cowpea variety, SAMPEA-7, + 120 kg N, 26 kg P and 50 kg K per ha.
3) Farmers variety of maize and cowpea (one each) + 60 kg N, 13 kg P and 25 kg K per ha.
4) Farmers variety of maize and cowpea (one each) + 120 kg N, 26 kg P and 50 kg K per ha.

A randomized complete block design was used. Each farmer constituted a replicate of four treatment combinations. Maize variety TZBSR-W is an open-pollinated, streak resistant type that matures in about 120 days. The improved cowpea variety, SAMPEA-7, is a photo-insensitive, brown-seeded, semi-spreading medium maturing (70-75 days) type. The fertilizer rates of 120 kg N, 26 kg P and 50 kg K per ha represent the official fertilizer recommendation for open pollinated maize varieties in the areas where the study was undertaken.

Maize was sown on ridges from early June to early July while cowpea was planted between maize stands, 6-8 weeks after sowing maize. In all cases, the fertilizer was applied to maize in two split doses as NPK (27-13-13) half at two weeks after sowing (WAS) and half at 6 WAS. All the fertilizer was applied by placement alongside maize plants. All treatments and cultural management practices from land preparation to harvesting were applied by farmers. However, the technical staff of the Institute for Agricultural Research (IAR) who were stationed in the villages gave advice on management practices. The cowpea component was protected against insect pests by two applications of a tank mixture of 50 g a.i./ha of Karate EC and 250 g a.i./ha of dimethoate (Perfekthion 40EC) - one application at flowering and the other at pod filling.

Data were collected on pre-cropping soil conditions, operational and input costs and grain yields.

Results and Discussion

Maize grain yield

Data on the effects of variety and fertilizer on maize grain yield showed that at all three locations, the improved variety TZBSR-W significantly outyielded the farmer's variety (Table 3). Averaged over locations and years, the magnitude of yield increase over the farmer's variety was 15%, with a range of 4-35%. The yield difference between the improved variety and the farmer's variety was greater at Daudawa and Makarfi than at Malumfashi. In general, the difference between the yield of improved variety and the farmer's variety was not much. This could be attributed to the fact that virtually all farmers in the savanna zone grow improved maize varieties. Thus, the farmer's variety is actually an improved variety. It is notable, however, that on the average, maize variety TZBSR-W outyielded the farmer's variety. There was a high degree of yield variability among farmers and between locations mainly due to differences in sowing dates and probably crop management.

Table 3. Maize grain yields (kg/ha) as affected by variety and fertilizer in maize/cowpea mixtures at Daudawa, Makarfi and Malumfashi in the 1992-1994 wet seasons.

Treatment*	Daudawa			Makarfi		Malumfashi	
	1992	1993	1994	1993	1994	1992	1994
T1	1532	2288	2012	1786	2151	2901	1713
T2	2448	3042	2392	2627	2587	3410	1840
T3	1394	2025	1340	1352	1787	2781	1671
T4	2399	2514	1919	1969	2313	3144	1742
SE+	92.5	106.7	105.2	102.9	59.6	63.2	12.9
LSD (5%)	266.5	306.3	303.1	291.2	169.8	178.8	36.5
CV (%)	16.5	15.6	19.0	23.3	10.8	9.2	3.3

* T1 = TZBSR-W + 60 - 13 - 25 NPK
T2 = TZBSR-W + 120 - 26 - 50 NPK
T3 = Farmers variety + 60 - 13 - 25 NPK
T4 = Farmers variety + 120 - 26 - 50 NPK.

Averaged over locations and maize variety, grain yield increased by 28% with application of 120 kg N, 26 kg P and 25 kg K per ha. Yield differences due to fertilizer application were highly significant at all locations. The soils of the experimental sites are low in nitrogen, phosphorus and organic carbon (Table 2). Although the recommended fertilizer rates for maize in these areas are 120 kg N, 26 kg P and 50 kg K per ha, most peasant farmers apply far less than these rates due to scarcity of fertilizer caused by the poor distribution system and soaring cost, following the gradual removal of subsidy. Farmers try to improve low soil fertility by applying farmyard manure but this commodity is in short supply; consequently, the quantity applied per unit area is usually small. Fertilizer recommendation for maize in the savanna zone was based on results obtained from studies conducted on-station and at government farm centers. The results from the present on-farm study have demonstrated that despite the fact that farmers apply farmyard manure, maize yield will be reduced if the recommended rates of fertilizer are not used.

Cowpea grain yield

The effects of variety and fertilizer on grain yield of cowpea are presented in Table 4. Averaged over locations and years, improved variety SAMPEA-7, outyielded the farmers variety by 41%, the range being 6 to 78%. The magnitude of yield increase was highest at Daudawa followed by Makarfi while Malumfashi recorded the lowest yield increases.

Table 4. Cowpea grain yields (kg/ha) as affected by variety and fertilizer in maize/cowpea mixtures at Daudawa, Makarfi and Malumfashi in the 1992 to 1994 wet seasons.

Treatment*	Daudawa		Makarfi		Malumfashi	
	1993	1994	1993	1994	1993	1994
T1	537	508	148	224	256	217
T2	658	633	191	254	297	231
T3	325	278	96	182	243	197
T4	422	362	139	222	278	203
SE+	29.1	39.3	11.0	9.0	5.2	3.5
						9.9
LSD (5%)	83.4	113.3	31.0	25.6	14.6	7.3
CV (%)	21.6	30.6	34.2	16.3	8.6	

* T1 = SAMPEA-7 + 60 - 13 - 25 NPK
T2 = SAMPEA-7 + 120 - 26 - 25 NPK
T3 = Farmers variety + 60 - 13 - 25 NPK
T4 = Farmers variety + 120 - 26 - 50 NPK.

Four out of the 12 farmers who participated in the project at Daudawa in 1992 did not obtain cowpea grains. Moreover, during harvest, the farmers only separated the two varieties without taking fertilizer treatments into consideration. Therefore, only the performance of the two varieties could be assessed. Results showed that SAMPEA-7 outyielded the farmers variety by 32% (Table 5).

Table 5. Cowpea grain yield at Daudawa in the 1992 wet season.

Variety	Grain yield (kg/ha)
SAMPEA-7	431
Farmers variety	295
SE+	17.4
LSD (5%)	58.1
CV (%)	13.6

***, significant at the 0.001 probability level; ns, not significant.

Cowpea grain yield responded favourably to fertilizer application at all locations. Averaged over variety and locations, the application of 120 kg N, 26 kg P and 50 kg K per ha resulted in 21% increase in cowpea grain yield over 60 kg N, 13 kg P and 25 kg K per ha. This demonstrates that the cowpea crop grown in relay with maize benefited from part of the fertilizer applied to maize.

Cowpea grain yield was much higher at Daudawa compared with Makarfi and Malumfashi. For example, in 1993 average yield of SAMPEA-7 in mixture with maize given 120 kg N, 26 kg P and 50 kg K per ha was 625 kg/ha (range of 340-1080 kg/ha) while that of a similar treatment at Makarfi was 191 kg/ha (range of 30-370 kg/ha). The better performance of cowpea at Daudawa compared with the other locations could be attributed to early planting of maize. Thus, there was less competition between maize and cowpea because after maize harvest, cowpea was exposed to more favourable light conditions during reproductive development.

Labour requirements

Tables 6 and 7 reveal that labour for harvesting was 25-43% of the total labour requirements, while 19-23% of the total time was utilized in shelling/threshing. The improved varieties required slightly more labour than the local varieties, with most of this labour going into the harvesting of the improved cowpea variety. Total labour requirements were lower at Daudawa compared with Makarfi in 1994, mainly because farmers at Daudawa used animal power for ridging and moulding-up.

Table 6. Labour requirements for production of a hectare of maize/cowpea mixture at Daudawa in the 1993 wet season.

Operation	Treatment			
	T1 Improved maize and cowpea + 50% fertilizer dose.	T2 Improved maize and cowpea + full fertilizer + dose.	T3 Local maize and cowpea + 50% fertilizer dose.	T4 Local maize and cowpea + full fertilizer dose.
	manhours/ha			
Land preparation	12	12	12	12
Planting (maize)	26	26	26	26
Weeding	76	76	75	75
Fertilizer application	39	42	39	39
Earthing up	13	13	13	13
Planting (cowpea)	32	32	32	32
Spraying (cowpea)	10	10	10	10
Harvesting-maize	172	172	172	172
Harvesting cowpea	108	108	77	77
Shelling of maize	84	85	83	83
Threshing of cowpea	55	55	52	52
Total	627	631	591	591

Table 7. Labour requirement for production of a hectare of maize/cowpea mixture at Daudawa and Makarfi in the 1994 wet season.

Operation	Treatment T1 Improved maize and cowpea + 50% fertilizer dose.	T2 Improved maize and cowpea + full fertilizer + dose.	T3 Local maize and cowpea + 50% fertilizer dose.	T4 Local maize and cowpea + full fertilizer dose.
	manhours/ha			
	DAUDAWA			
Ridging	9	9	9	9
Planting (maize cowpea)	58	53	47	47
Weeding	133	133	115	122
Fertilizer appl.	10	10	10	10
Earthing up	30	35	30	29
Spraying (cowpea)	13	12	13	13
Harvesting (maize cowpea)	205	214	181	201
Shelling/threshing	105	105	99	102
Total	558	569	504	531
	MAKARFI			
Ridging	90	90	74	74
Planting	60	61	58	59
Weeding/fertilizer appl.	150	149	151	144
Earthing up	94	96	102	99
Spraying (cowpea)	4	4	4	4
Harvesting	185	188	172	170
Shelling/threshing	132	132	132	132
Total	715	720	693	682

* Ridging and moulding up were done by the use of animal power at Daudawa.

Financial costs and returns

The gross margin analysis shows that the net returns per hectare for improved varieties of maize and cowpea were 87% and 82% higher at Daudawa in 1993 and 1994, respectively, compared with the farmers varieties of both crops (Tables 8 and 9). A modest increase of 31% was obtained at Makarfi in 1994 using improved varieties of maize and cowpea compared with farmers varieties (Table 10). Similarly using the full dose of fertilizer, net returns increased by 57% and 45% at Daudawa in 1993 and 1994, respectively, compared with half dose of fertilizer. At Makarfi, an increase of 50% in net income was recorded by adopting the full fertilizer dose instead of half dose. The differences in net returns per hectare were mainly due to the differences in yields rather than in costs of production. The results clearly indicate the economic benefit of using improved varieties of maize and cowpea and also the recommended fertilizer rates.

Table 8. Gross margin analysis (NGN/ha) of maize/cowpea mixture at Daudawa in the 1993 wet season.

Operation	T1 Improved maize and cowpea + 50% fertilizer dose.	T2 Improved maize and cowpea + full fertilizer + dose.	T3 Local maize and cowpea + 50% fertilizer dose.	T4 Local maize and cowpea + full fertilizer dose.
Variable cost				
Labour	6270	6310	5910	5910
Seed - cowpea	100	100	64	64
maize	40	40	40	40
Fertilizer (NPK 27:13:13)	1000	1800	1000	1800
Total variable cost (TVC)	7410	8250	7014	7814
Revenue				
Maize	9666	11844	5706	7596
Cowpea	7322	9734	6480	7306
Total revenue (TR)	16988	21578	12186	14902
Gross margin (TR-TVC)	9578	13328	5172	7088

Footnotes:
Labour valued at NGN10/hr; Fertilizer valued at NGN4/kg; Cowpea seed valued at NGN25/kg; Maize seed valued at NGN10/kg; Cowpea grain valued at NGN18/kg; Maize grain valued at NGN3.20/k

Table 9. Costs and returns (NGN/ha) from maize/cowpea on-farm trial at Daudawa in 1994.

Operation	Treatment			
	T1 Improved maize and cowpea + 50% fertilizer dose.	T2 Improved maize and cowpea + full fertilizer + dose.	T3 Local maize and cowpea + 50% fertilizer dose.	T4 Local maize and cowpea + full fertilizer dose.
Revenue				
Maize	16096	19056	10720	15352
Cowpea	9144	11394	5004	6516
Total revenue (TR)	25240	30450	15724	21868
Variable cost				
Seed-maize	400	400	80	80
cowpea	1400	1400	480	480
Fertilizer	864	1728	864	1728
Insecticide	975	975	975	975
Labour	7812	7966	7056	7434
Total variable cost (TVC)	11451	12469	9455	10697
Gross margin (TR-TVC)	13,789	17,981	6269	11,171

* Price assumption

Improved maize seed = NGN10.00/kg; maize grain = NGN8.00/kg
Improved cowpea seed = NGN35.00/kg; cowpea grain = NGN18.00/kg
Farmers maize seed = NGN4.00/kg; fertilizer (NPK 27:13:13) = NGN3.60/kg
Farmers cowpea seed = NGN24.00/kg Labour= NGN14.00/man-hr
Insecticide = NGN65.00/litre.

Table 10. Costs and returns (NGN/ha) from maize/cowpea on-farm trial at Makarfi in 1994.

Description*	Treatment			
	T1 Improved maize and cowpea + 50% fertilizer dose.	T2 Improved maize and cowpea + full fertilizer + dose.	T3 Local maize and cowpea + 50% fertilizer dose.	T4 Local maize and cowpea + full fertilizer dose.
Revenue				
Maize	17208	20696	14296	18504
Cowpea	4032	4572	3276	3996
Total revenue (TR)	21240	25268	17572	22500
Variable cost				
Seed - maize	200	200	80	80
cowpea	700	700	480	480
Fertilizer	864	1728	864	1728
Insecticide	650	650	650	650
Labour	10010	10010	9702	9548
Total variable cost (TVC)	12424	13358	11776	12486
Gross margin (TR-TVC)	8816	11910	5796	10014

* See Table 10 for price assumptions.

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Chapter III

Technology Transfer

New Orientation and Challenges of Technology Transfer to enhance Food Production in Africa

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Abstract

The development, processing, production, dissemination and utilization of improved technologies in Africa's agriculture have been subject of speculation, research and discussion at several workshops, seminars and conferences. Often times, the emphasis is on structural and institutional designs, modalities and methods, procedures and impacts, problems and constraints in the process of information and skill delivery from centres of technology development and production to agricultural end-users (farmers) where they live and work. The process has been evolutionary and has taken on different characteristics (though with great similarities) and nomenclatures in different countries. It transcends the advisory services of the United Kingdom through the Agricultural Extension Services of the United States of America, to the more contemporary concepts of agricultural development projects, specialized commodity production parastatals and modern educational approaches of integrated rural development. It has been construed as a subject-matter area of learning (discipline), a function of Government Agency and a programme of deliberately influencing the behaviour of a given client group (farmers). Over the years, the contextual reality of technology transfer has changed, due partly to alterations in population growth and movements, industrial development, basic changes in agricultural production systems, environmental imperatives (climate change, drought, flood, etc.), civil strife and severe food deficits.

But perhaps, the most important reason for concern is the recent realization that while agricultural research in Africa has made substantial progress in the development of new technologies, the correct application of which should result in increased food production, the desired impact is hardly noticeable, due in part, to ineffective technology transfer mechanisms.

In this paper, an attempt is made to review past models and efforts at technology transfer in agriculture, with a view to revalidating reasons for failure and/or limited success. The paper postulates that in order to prevent the mistakes of the past, there is a need for a new orientation, consistent with the perceived challenge of food production in the 21st Century. This orientation, grounded in theory and practice, should take due cognisance of the multi-dimensional and multi-disciplinary nature of the problems involved in technology development and transfer process in order to steer a relevant course essential to meeting the challenge ahead.

Résumé

La mise au point, la transformation, la production, la diffusion et l'utilisation des technologies améliorées dans le cadre de l'agriculture africaine ont fait l'objet de spéculations, de recherche et de débats au cours de plusieurs ateliers, séminaires et conférences. Souvent, l'accent est mis sur l'organisation structurelle et institutionnelle, sur les modalités et méthodes, les procédures et les impacts, les problèmes et les contraintes dans le processus d'information et de transfert de compétences à partir des centres de conception et de production des technologies vers les utilisateurs finaux agricoles (les paysans) dans leur milieu. Le processus a évolué et a revêtu différentes charactéristiques (grandement similaires cependant) et nomenclatures dans les différents pays. Des services consultatifs du Royaume Uni en passant par les Services de Vulgarisation Agricole des Etats Unis d'Amérique, il aboutit à des concepts plus contemporains de projets de développement agricole, d'établissements para-étatiques spécialisés en production de cultures et d'approches pédagogiques modernes en matière de développement rural intégré. Il a été interprêté comme un domaine d'enseignement (discipline), la fonction d'un organisme gouvernemental et un programme tendant à influencer délibérement le comportement d'un groupe donné de clients (les paysans). Au fil des années, la réalité contextuelle du transfert de technologies a changé et cela en partie à cause de la croissance et de la mobilité des populations, du développement industriel, des changements fondamentaux des systèmes de production agricole, des impératifs environnementaux (changement climatique, sécheresse, inondations, etc.) des conflits et des graves déficits alimentaires.

Peut-être que le motif de préoccupation le plus important est la prise de conscience que malgré les progrès considérables réalisés en Afrique par la recherche agricole pour la mise au point de nouvelles technologies dont l'application correcte devrait permettre d'accroître la production vivrière, l'impact souhaité est à peine remarquable en raison de l'inefficacité des mécanismes de transfert des technologies.

Cette communication tente de passer en revue les modèles et efforts antérieurs de transfert de technologies, afin de faire ressortir les raisons de l'échec et/ou du succès limité. Selon l'argumentation de la communication, pour éviter les erreurs du passé il faudrait une nouvelle orientation conforme aux objectifs perçus de la production vivrière au cours du 21è siècle. Cette orientation, basée sur la théorie et la pratique devrait tenir compte de l'aspect multidimensionnel et multidisciplinaire du problème posé dans le processus de mise au point et de transfert de technologies afin de prendre le bon chemin, condition essentielle pour relever le défi lancé.

Introduction

Agricultural research is perhaps the most important single determinant of agricultural development in sub-Saharan Africa. This is because no nation has been known to have achieved any meaningful progress in agricultural growth without huge investments in agricultural research. In Africa, the food, agriculture and natural resources sector occupies a central position in the economic structure. Consequently, its development has obvious implications for overall development.

The need for agricultural research in Africa has always been informed by the frequently mentioned problems of poor productivity and incessant and intractable food shortages. The reasons for failure to achieve food self-sufficiency and food security are many and varied. It is often argued that much remains to be done in improving technologies, modernizing obsolete structures, reviewing the technology utilization capacity of the resource poor farmer and, more importantly, integrating the small farmer into the improved agricultural production and development process. By implication, it is assumed that success is achievable through effort to upgrade and revitalize the entire system of agricultural research, technology development and transfer.

Experience of some developed countries suggests that significant progress was achieved in agricultural development as a result of machines (technology) invented and manufactured during the industrial revolution. The development of "agricultural science" and a research and educational concept were major facilitating factors.
The acceleration of the growth rate in the agricultural sector, its transformation from subsistence to a commercially viable activity, and its diversification were dependent on research focussed on the development, spread, adoption and use of modern agricultural technology.

The last twenty years has witnessed enormous investment in agricultural research and development of new technologies in Africa. The national and international research centres have reported significant yield increases in maize, rice, sorghum, cassava, yam, cowpea, soybean, etc. Insect pest and disease damage to plants, animals and crops have been brought under substantial control. Fertilizer technology is no longer a novelty. The list is long and impressive, yet, the African small farmer remains relatively unaware of, or lacks the skill and/or resource to take full advantage of, what agricultural research has made available through new and improved technology.

In this short discussion paper, an attempt is made to focus on the concept of the transfer of research results and technology in Africa's agriculture. The modalities for the transfer of agricultural research results are identified. The paper posits that effective transfer of agricultural research result and technology is achieved where and when cooperative relationships are established among research, technology transfer and rural farmers as equal partners in the technology development and utilization process.

The Problem and Challenge of Technology Development and Transfer in the 21st Century

The thrust of African Governments to create viable, stable and democratic economies is heavily dependent on the agricultural sector. This is because agriculture is the primary source of employment, domestic food supply and foreign exchange earnings. Agriculture supplies raw materials for domestic industries, creating the required demand for consumer goods and commercial inputs with a direct impact on the non-agricultural sectors of the economy. Also, agriculture plays an important role in food self-sufficiency and security at national and household levels.
Yet, the contribution of agriculture to gross domestic product of Africa in the aggregate has dropped to 32.4 per cent in 1991, from 37.9 per cent in 1965. Even though individual African nations may show increases in agriculture and food production, such improvements may have been offset by disproportionate increases in population.

Thus, the agricultural economies of Africa have continued to portray a crisis characterized by: (i) a decline in per capita food and agricultural production; (ii) a decrease in agricultural export earnings; (iii) a degradation of the environment occasioned by careless over-exploitation of the natural resource base; (iv) increasing population pressure; and (v) poor performance of agricultural investments.

The above scenario draws attention to two particularly relevant factors in the African agriculture and food crisis consideration, viz., the relatively low rate of technology development and technology transfer and utilization in African agriculture. The combined effect of both factors may explain the greatest limit situation and stagnation in Africa's agricultural productivity. Therefore, if Africa has to cope with the challenges of the 21st century, it must transform its agricultural base as a pre-condition to significant and sustained economic growth and social development.

An analysis of current world order and events would suggest that agriculture and food production programmes of the 21st century would have to face up to the challenge of: (i) increasing food security and self-sufficiency described as adequate access by all people at all times to sufficient food and nutrition for a healthy and productive life; (ii) increasing the competitiveness of African agricultural commodities and products in the world and regional markets; (iii) increasing the income level of the broad masses of the population through increased gainful employment in agriculture; and (iv) maintaining and enhancing a sustainable capacity of the natural and genetic resource base for the benefit of agricultural development.

For Africa to adequately deal with the perceived challenge, there is need for collaborative reorientation between policies and actions in a wide range of activities covering policy, infrastructure, support services, human resource development, farmer participation, technology development, validation and transfer.

Technology Transfer: Issues of Operational Definition and Terminology

Technology transfer in its original connotation was used to imply the transfer of industrial art in a developed system. In that context, Vitta (1990) defines technology as the "knowledge and procedure used to transform inputs derived from the natural environment into useful output, normally called goods and services". It can also refer to the logistics and social relations of production or to the style of presenting and delivering the final production.

Agricultural technology, in specific terms, may be defined as the overall combination of complementary techniques employed in the production of goods of market value. It is sometimes conceived as consisting of "software" and "hardware", e.g., fertilization is one such technique, while maize growing in all stages is undertaken by means of an agricultural technology. Roling (1989) refers to technology partly as "software" - accumulated knowledge which has proved effective in exerting control in the real world... and partly as "hardware", such as seeds, tools, equipment, and programmes in which knowledge is embodied. It can be an idea, a physical object, or an abstract entity.

Technology transfer in its contemporary usage in agriculture has been defined as a "process by which the recommended practices developed and perfected at research institutes are transmitted through the extension agents to users". It encompasses three main sub-systems: (i) the technology generation/research sub-system, (ii) the technology utilization/clientele sub-system, and (iii) the technology dissemination/extension sub-system.

The resort to technology transfer as a complement to extension seems to have been as a result of the search for a more, all-inclusive terminology to articulate programmes, activities, actors and facilities external to the traditional extension service. Popularized by the ISNAR study group, it has become more fashionable to speak of technology transfer as a complement to extension because: (i) it is important to include the role of input and other service institutions in the analysis of technology development, delivery and utilization; (ii) the teaching-learning and educational approach often associated with extension is de-emphasized in technology transfer studies; and (iii) extension is usually associated with, and tends to be confined to, the traditional public sector extension service, while in the analysis of technology transfer, full consideration is given to the role of other institutions such as private firms, parastatals, NGOs, producer associations, etc.

In its general usage, the terminology "technology transfer" is not restricted in meaning to the one way flow of information, knowledge, skills and materials from those who develop and deliver technology to those who use it, but implies a two-way flow of technical information between these groups.

The technology transfer process is a difficult concept to operationalize in real life. This is because of the several barriers to the technology transfer process. Baron (1990) in his study, for example, identified several barriers to the transfer of profitable technologies developed at national laboratories at tax payers' expense to the private sector industrialists. Technology transfer initiatives by Government seem to run contrary to of end-users perceptions. Often times, industrialists and agricultural entrepreneurs visit national technology development laboratories and research centres with a view to acquiring a technology "nugget" only to find that a specific resultant product of the technology development process is not sitting on the shelf to be moved into the commercial sector. "Some of these venture capitalists have no appreciation of the technology nor the effort required to bring a good idea into the market place". Some research and development scientists, though well trained, competent and experienced, have no idea of how to transfer technology within or between organizations. In some cases, there is a cultural difference between the research technology development and the technology application departments which blocks information flow and technology transfer between them. This gap must of necessity be bridged.

In other circumstances, basic research is undertaken for research sake with no specific product in mind. Results are reported openly and discussed freely at several fora. There is usually no cost-benefit analysis to ascertain acceptable levels of investment. Some researchers are highly protective of the research they undertake and resent any dilution of their pure studies and research prowess with demand for industrial and field application.

In industry and agriculture, the approach to research is more often with a short term orientation, bearing in mind the desire for directly applicable, mission-oriented objective for return on investment. Confidentiality of information is essential in order to retain competitiveness. This behaviour pattern can only inhibit information exchange and technology transfer even though it could enhance technology development.
Yet, in other cases, barrier to technology transfer has been occasioned by the fact that mechanisms that promote and facilitate technology transfer from agricultural research centres to farmers' are either: (1) poorly developed or not available at all; or (2) obsolete, or tenacious, economic, legal or social barriers exist that prevent a more cohesive research-technology transfer-end-user (farmers) interface.

Sometimes, the problem is endemic in the technology development and transfer environment. The logic in the decision process of farmers to adopt a given technology is sometimes difficult to understand. Consequently, it could become problematic to design strategies for technology transfer to accelerate the adoption - decision process.
Finally, most of the problems of technology transfer derive from the nature of the technology transfer system itself. The stereotype agricultural research scientist often concentrates on the technology itself, without giving adequate thought to how to transfer it. The assumption often is that if the technology is profitable and solves a given problem, then those who need it will spontaneously acquire it; which is often not the case. There are several reasons for this.

Firstly, the technology transfer system does not of itself initiate the process or generate technology. It is primarily a conduit for technology delivery to the farmer. Sometimes, however, it may be involved in technology modification. Consequently, if the technology generation system is deficient, passive or inoperative, the technology transfer system is immobilized and dysfunctional. Secondly, the main function of the technology transfer system is knowledge, skill and material transfer. It tends to be geographically dispersed and operates downstream, mainly at the farm level. Therefore, good logistic support becomes essential for effective performance. Thirdly, technology transfer arrangements are often fragmented. Consequently, functional linkages between research, technology transfer operatives and farmers, as well as active feedback mechanism, are a pre-conditions for success. Finally, government policy and intervention can sometimes constitute a constraint.

The Need for Transfer of Agricultural Research Results and Technology

It has been generally acknowledged that in order to contribute to development in Africa, agricultural research needs to be innovative and relevant and its results widely transferred and/or acquired by those who require it. It is also a statement of fact that increased farmers productivity requires access to new and improved technologies. These technologies derive largely from agricultural research. For agricultural research to remain relevant and attract desired investment for its sustenance, it must tackle user priority needs and problems. There is evidence that research recommendations applied and advocated at national agricultural research centres are frequently not adopted, even by farmers resident just outside the research stations. The need for concerted effort and organized responsibility for technology transfer has therefore become an added responsibility of agricultural research. For effective technology transfer to take place,

there must be effective coordination between agricultural research, technology development and transfer at all levels. In most cases in Africa, this does not happen, due mainly to the fact that available important services are considered as performing parallel functions. Consequently, both functions -agricultural research and technology transfer - are considerably weakened.
The need for organized and systematized technology transfer programme in Africa's agricultural research system is further justified by the frequent reasons adduced for poor dissemination of agricultural research results. Some researchers claim that the farmer is at fault, suggesting that preferences, based on traditionalism, lead farmers to reject unfamiliar technologies.

Some castigate agricultural extension services, arguing that the utility of new and improved technologies has not been adequately demonstrated to farmers. Others insist that inadequate credit limits farmer ability to adopt technologies. Some indicate that inputs, essential to technology acquisition and use, are not available on time and at affordable price. But, less frequently mentioned, are problems of inappropriate technology for farmers adoption.

Shaner *et al*. (1982) indicate that the endemic problems of technology transfer are further compounded by a research orientation "that farmers cannot generate and provide information that is useful for improving technologies and that technology transfer workers (extension workers) are professionally inferior and therefore have little to contribute".

Realizing that agricultural research has little merit unless it leads to adoption and use of a derived technology by farmers, the challenge facing agricultural research systems in the 21st Century Africa becomes obvious. Agricultural research systems must, therefore, conceptualize an effective mechanism and develop the capacity to implement the transfer of their research results and technologies. It has been suggested that this may require shifts in research policies and priorities, changes in the organization and management of research and technology transfer agencies and the development of functional links between these agencies and farmers. One has been around long enough to know that some of these changes and experimentation with methods and approaches have been undertaken. Yet the problem persists. It is my fervent hope that this workshop is one effort to look, yet more closely, at how past changes have been implemented.

Most agricultural development experts believe that achievements in increased agricultural production recorded during the late colonial and immediate post-independence era, which were due mainly to the expansion of land under agricultural production, will no longer be possible as Africa enters the 21st century. They argue, and I agree with them, that beyond the year 2000, information on new technologies, will become the key element in increasing yields and improving overall agricultural production. The developed world is already speculating that biotechnology is expected to drive yield increases in the future. Also, a greater use of improved technology and management will be a key factor in increased productivity per head in animal production. Sustainable agricultural development and environmental protection are also predicated on the rational use of agricultural research result, the benefit of which will depend on access and transfer.

In the early stages of agricultural growth, research was simple and technology transfer may have been undertaken through copy, imitation or borrowing. With advances in the application of science and agriculture, Africa has been more conscious and has evolved a technology sharing process involving a wide range of specialists dispersed over a wide technology transfer continuum. This advance has produced new problems which in themselves require new theories, research and approaches to resolve. In general, and deriving from the need to formally organize the transfer of agricultural research results from research institutes to farmers, African nations have opted for a systematized and specialized approach generically described as "agricultural extension".

This specialized activity, be it general extension service, training and visit approach, farming systems research, networking, research-extension linkage, agricultural extension research liaison service, etc. has several problems, three of which are very important to the issues discussed in this paper. These problems include the following.

(i) *The lack of effective linkage among specialized functions*: Merrill-Sands and Kaimowitz (1989) in a recent study asserted that "links between agricultural research institutes and their clients - farmers and technology transfer agencies (extension) - are vital to successful technology development and delivery. Direct links with farmers developed through on-farm adaptive research, ensure relevance and feed-back". The two links are complementary, both are necessary and one cannot substitute the other. Research managers have found these links difficult to organize and sustain, particularly when addressing the needs of resource poor farmers. Yet, experience has shown that weak links have costs, which few African countries can afford. Linkage problems, not only reduce efficiency, they also impair performance and diminish the impact of agricultural research. The problem of weak linkages in agricultural research and technology transfer has been exacerbated with the adoption of the Specialized Technology Transfer option and its concomitant compartmentalization of functions.

(ii) *The lack of relevance of the technologies developed under systems based on predominantly one-way flow of information from scientists to farmers*: The research agenda is, traditionally, set by the agricultural scientists and researchers with less than adequate input from the end-user of agricultural research results. Sometimes the interaction between scientists within the same organization is limited. It has been argued by some experts that specialized technology transfer systems have become highly inefficient, due in part, to specialization of disciplines and staff deployment at various stages of the process, resulting in communication break down among actors and loss of information and knowledge in the process. The practice of specialized technology transfer approaches has been further reinforced by the belief that agricultural development implies a shift from traditional methods of production to new science based methods of production that include new technological components, new crops, animals and sometimes, new farming system. Borrowing a leaf from industry and management theory, agricultural scientists have come to accept that specialization of functions is the best way to organize work in order to enhance efficiency. However, where specialized technology transfer functions are not well planned and managed to ensure complementary interaction among actors, it can lead to development of inappropriate technologies, existence of missing functions, and inefficiency.

(iii) *Lack of access to knowledge of available research results and technologies*: For farmers to benefit from agricultural research results and new technologies, they must first know about them, learn about them and learn how to use them correctly in their farming programme. Where the technology is a physical input, they must have access to it at an affordable cost. The issue of availability and access, as a primary factor in technology transfer, is well known.

Transfer of Agricultural Research Results and Technology: Experience with Some Approaches

Critics of agricultural research in Africa and elsewhere have increasingly raised concern about the dominant position that research must originate from the top and diffuse downwards to the farmers. It has been argued that research, technology development and transfer must be viewed more and more as catalytic processes of "freeing the creative forces of the impoverished and exploited of the Society and enabling those forces to come to grips with the problems of under-development". This contention has prompted the search for alternative approaches, reflecting several concerns:

That quantitative research methods are not providing for an adequate understanding of the complex reality of the agricultural production process in a predominantly non-literate society; and the desire for practical research that can be used as a basis for setting policy and developing programmes that will promote social justice and greater self-reliance. The premise being a view of human behaviour which sees individuals as active participants and agents of development in their environment rather than passive objects to be researched.

Until very recently, farmers in Africa have been served by researchers and technology transfer agencies through what can be described as a "delivery oriented" approach. There has been an extensive concentration on deliveries (technologies and supplies) to farmers without adequate corresponding effort to enhance the capacity of farmers to lay claim to these deliverables and become self-sufficient. The delivery oriented approach to technology transfer has been criticized for marginalizing and disempowering the African small farmer. The approach was based on the assumptions of conventional research and extension which are in sharp contrast with the emerging liberating assumptions of participatory research and extension. According to the proponents of this approach to the transfer of agricultural research results and technology, the factors which have constrained the development and transfer of technology in sub-Saharan Africa include: (i) the fact that farmers are frequently spatially and politically marginalized and hence poorly served by research and extension; (ii) the tendency for researchers and technology transfer functionaries, through their top-down professional orientation, to be dismissive of farmers' apparent reluctance to change; (iii) the likelihood that the reductionist scientific methods which examine individual commodities or technologies without a holistic outlook, will produce misleading recommendations where systems interaction are strong; and (iv) the apparent neglect of the importance of farmers' indigenous knowledge of their complex and highly variable real life environment.

From the above analysis, it can be seen that a demand driven technology transfer system really never existed in Africa, until very recently, through the Agricultural Development projects, designed to interface between researchers formal work plan and farmers indigenous knowledge, in order to take advantage of the best of each. It is now increasingly evident that since the farmer is the common denominator in the technology transfer process, he must get into the equation.

A recommendation that has often been made is for research and technology transfer to interact more frequently in order to better understand each other's objectives, interests and capabilities, in the interest of the technology transfer process. The approaches, in recent times, directed at a more effective transfer of agricultural research results and technology have been informed by the above considerations.

The functions of technology transfer systems are organized differently from country to country. Some countries have experimented with various options, most of which have been subject of extensive investigation and recommendation. The general characteristic is that they are all public sector activity, even though they have been organized and implemented differently with varying effectiveness. These approaches are common knowledge and include the following:

(i) The conventional agricultural extension approach exemplified by the pre-independence advisory service and the post-independence national extension services (vulgarisation agricole). Their general objective was increased food crops, export crops and animal production. The impact was substantial in the early years, but it soon slipped into decay and became relatively dysfunctional in later years.

(ii) Commodity Extension Approach - characterized by cocoa, oil palm, banana, rubber, rice and groundnut parastatals in several African countries. The guiding principle was that a specialized technology transfer system with a known package of recommendations supported with a firm research and development programme will be more effective. The intent was to develop a production system to effectively satisfy the market demand for relatively high value commodities. This approach was successful for as long as the commodities enjoyed competitive world or domestic market prices and farmer demand for high technology was sustained. But, government policy changed in the early 1980s as food security became a major objective. Most farmers withdrew resources from export crops, the demand for technology collapsed, and the technology transfer systems were dismantled.

(iii) Integrated Approaches to Technology Transfer, typified in Africa, by the advent of the Integrated World Bank Assisted Projects - Agricultural Development Projects and the accompanying Training and Visit System. Integrated approaches to technology transfer surely have merit, but, the African experience did not absolve it of the usual criticism of high cost and rigidity of organization.

The above three major approaches have been complemented with the following:

. Farming systems research and extension approach;
. University technology transfer research and development programmes;
. Participatory rural appraisals and surveys;
. Rural research committees and NGO pilot projects; and
. Rural animation and general awareness programmes in agriculture; etc.

Every one of the above efforts had a significant technology transfer component with extensive input by the research and technology transfer systems. Yet, the problem persists. So what is wrong? That is the question that I believe this workshop is organized to partially answer, so that Africa can better chart its future course.

Conclusion and Suggestions

Our continent is currently faced with the serious problems created by climatic instability, food deficits, lack of foreign exchange and severe debt burden, rapid population growth, environmental scourge, and limited progress in food production. Under this condition, it is necessary to combine short-term measures to push growth as fast as possible with a long-term approach to develop and transfer new technologies and techniques to end-users in agriculture.

In this discussion paper, an attempt has been made to discuss the transfer of agricultural research results and technology against a background of an evolving system dedicated to improved agricultural production through the application of science. Over the years, Africa has experimented with various technology transfer approaches in the technology transfer process. The approaches have been informed and sustained without adequate recognition of the role of the farmer in the development and transfer of technologies developed through research. Unfortunately, the desired effect is always not achieved. The several policy changes and re-organization of the research, technology development and transfer system notwithstanding, the adoption of available technologies by the small-scale farmer remains an intractable problem.

As Africa approaches the 21st century and contemplates a new orientation to development, the issue of the transfer of agricultural research results and technology is revisited. There is evidence to suggest that the conventional top-down approach to the determination of agricultural research agenda has not served its purpose. A participatory research and technology transfer approach is suggested. This orientation is not new, since it fits well into the farming system research approach and the on-farm, client oriented research paradigm for the development and transfer of technology. It will be very complementary to the Training and Visit system of extension which is the most recent organizational and administrative innovation in technology acquisition in most African countries. If through joint participation, cooperative relationships are established among research, technology transfer institutions and rural communities, all partners in the technology development process, there will be improvement in the level and rate of development, and cooperation between specializations will be further enhanced.

The African experience seems to suggest that: (i) no specific research strategy can substitute for technology transfer as a separate activity that must be planned for and adequately funded; (ii) researchers and technology transfer workers must collaborate and cooperate to ensure both the broad coverage required for impact and the site specific selection and adaptation of technologies; and (iii) research and technology transfer systems need each other.

Finally, let me conclude by making one remark and only one suggestion. Technology transfer is a researchable phenomenon to which too little attention has been paid in the

Le Système National de Vulgarisation Agricole au Burkina Faso: Acquis, Insuffisances et Perspectives

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Résumé

Le Burkina Faso, pays à économie essentiellement agricole a connu et expérimenté plusieurs options et méthodes de transfert de technologies depuis la période coloniale.

L'adoption d'un Système National de Vulgarisation Agricole (SNVA) en 1989 et sa généralisation à l'ensemble du pays répondait à l'époque au souci fondamental de renforcer le rôle de la vulgarisation agricole en tant qu'outil de transfert de technologies appropriées.

Aussi, l'organisation et le fonctionnement du SNVA au Burkina Faso, devraient permettre de maîtriser les questions fondamentales comme le rôle de la vulgarisation agricole, le type de services créés pour remplir ces fonctions, les conditions de travail et les relations avec d'autres unités au sein du processus pour trouver, adapter et diffuser de nouvelles technologies.

Après cinq années d'application de ce SNVA, quelques acquis et résultats positifs sont perceptibles malgré certaines insuffisances notamment le faible transfert des technologies existantes en milieu paysan.
C'est pourquoi les perspectives d'amélioration passent par un diagnostic de la situation et soulèvent certaines questions fondamentales sur le processus de transfert de technologies.

Abstract

Burkina Faso is a country with an essentially agricultural economy which has experimented several technology transfer options and methods since the colonial era.

The adoption of a National Agricultural Extension System (NAES) in 1989 and its expansion to the whole country was then a response to the fundamendal concern of strengthning the role of agricultural extension as a tool for appropriate technology transfer.

The organization and operation of the NAES in Burkina Faso should therefore contribute in handling the basic issues such as the role of agricultural extension, the type of services established to fulfil these functions, the working conditions and the relations with other units within the process so as to generate, adapt and disseminate new technologies.

After five years of implementation of this NAES; some achievements and positive results are noticeable in spite of some inadequacies, particularly the low transfer of existing technologies at famer's level.

That is why improvement prospects require a diagnosis of the situation and raise a number of fundamental issues regarding the technology transfer process.

Introduction

Situé au centre de l'Afrique Occidentale, le Burkina Faso couvre une superficie de 274 000 km² avec une population d'environ 10 millions d'habitants. L'économie est essentiellement dominée par l'agriculture qui occupe 87 % de la population active, intervient pour 35 % dans la formation du PIB et contribue pour 50 % des exportations totales. La pérennité et la croissance du secteur agricole sont donc des conditions préalables à tout développement socio-économique national. Cependant, les ressources naturelles (eau, sol, végétation), support de l'activité agricole connaissent une dégradation accélérée sous les effets conjugués de facteurs climatiques et des actions anthropiques. Pour faire face à cette situation, diverses stratégies ont été expérimentées. Les différentes approches de développement introduites dans le pays depuis la période coloniale jusqu'aux années 1980 se caractérisent par leur contenu productiviste et technologique, la faible participation des communautés de base et l'inadaptation des thèmes diffusés.

Aussi la politique actuelle de développement agricole du Burkina Faso vise:

- L'auto-suffisance et la sécurité alimentaire
- L'amélioration des revenus des populations rurales
- La protection de l'environnement.

Dans ce cadre, le pays a opté pour l'intensification, la diversification et la spécialisation régionale des productions agro-pastorales et la gestion des ressources naturelles avec la participation des populations. Pour ce faire une stratégie de vulgarisation adaptée aux conditions socio-économiques du pays a été définie à travers un système national de vulgarisation agricole.

Aperçu historique de la vulgarisation agricole au Burkina Faso

Plusieurs systèmes de vulgarisation agricole ont été conduits au Burkina Faso depuis la période coloniale jusqu'à nos jours.

A) De la période coloniale à 1966

La vulgarisation agricole a été conduite par les sociétés étrangères d'intervention telles SATEC, IRHO, CFDT, CIDR. Chaque société avait pour objectif l'accroissement de la productivité d'un produit donné comme le coton, les oléagineux etc... Dans ce cas, sont regroupées sous une même administration toutes les fonctions qui s'y rapportent, notamment :

- Recherche
- Vulgarisation.
- Approvisionnement en intrants et les équipements
- Commercialisation de la production.

Le financement de la vulgarisation était assuré par l'organisation de développement qui recherchait une rentabilité immédiate de ses investissements. La gestion à long terme des ressources naturelles et la participation des productions n'ont pas été toujours prises en compte.

B) Naissance de structures nationales de développement agricole

A partir de 1966, l'Etat Burkinabè, crée des structures nationales, notamment les organismes régionaux de développement (ORD), qui remplacent les sociétés internationales d'intervention.

De 1966 à 1988, les ORD ont élaboré et exécuté des programmes de développement agricole où toutes les principales cultures sont prises en compte. En matière de vulgarisation agricole chaque ORD avait sa méthode d'intervention ; il en est de même pour les ONG.

En 1981, la création d'un service national de vulgarisation est effective, il deviendra en 1988 la Direction de la Vulgarisation Agricole avec les mêmes missions: conception de méthodes et coordination des activités de vulgarisation agro-pastorale.

De 1984 à 1985 des journées de réflexion sur la vulgarisation agricole ont été organisées par le service national de vulgarisation. Les travaux de réflexion ont abouti à l'élaboration d'un système de vulgarisation cohérent pour tout le pays.

De 1986 à 1989, le Service National de Vulgarisation a testé ce système dans quelques ORDs à travers l'opération test de renforcement de la vulgarisation agricole (OTRVA) financée par la FAO, le FIDA et la Coopération Française.

En 1989, suite à un atelier d'évaluation qui a relevé les acquis importants de l'OTRVA, le système national de vulgarisation agricole a été généralisé grâce à l'appui de la Banque Mondiale à travers le projet de développement des services d'appui aux producteurs (PRSAP) et du PNUD.

Le système national de vulgarisation agricole (snva):Organisation et fonctionnement

A) l'objectif et principes de base du SNVA

Le système national de vulgarisation agricole (SNVA) du Burkina Faso est caractésé par l'approche communautaire, associative et intègre les aspects du 'Training and visit' et de Recherche-Developpement.

L'objectif prioritaire du SNVA consiste à: Accroître la productivité du travail agricole par l'application de techniques performantes, une meilleure gestion des exploitations, des revenus et des ressources naturelles (protection et restauration de l'environnement).

Pour atteindre cet objectif, le SNVA se fonde sur les principes de base suivants :

- L'organisation rigoureuse du réseau d'encadrement pour permettre une gestion rationnelle des ressources humaines et matérielles, assurer la couverture de tout le pays, toucher et former le maximum de producteurs.
- La programmation rationnelle des activités de vulgarisation à tous les échelons
- La formation continue des producteurs et des agents
- L'établissement de liens fonctionnels entre la recherche et la vulgarisation.
- Le suivi et l'évaluation des activités de vulgarisation à tous les niveaux du réseau d'encadrement.
- La collaboration et la concertation avec les structures partenaires pour une harmonisation des interventions.

B) Organisation du réseau d'encadrement

Le réseau d'encadrement de la vulgarisation agricole est subdivisé en plusieurs niveau, à savoir :

Le niveau village: Les villages sont organisés en Unités d'Encadrement Agricole (UEA) et en Unités d'Encadrement Elevage (UEE). Une unité d'encadrement comporte 8 villages en moyenne. Les UEA et UEE sont placées sous la responsabilité d'un agent vulgarisateur de base.

Le niveau département: Les départements sont organisés en Zone d'Encadrement Agricole (ZEA) et en Zones d'Encadrement d'Elevage (ZEE). La zone d'encadrement compte 5 unités d'encadrement et est sous la responsabilité d'un chef de zone.

Le niveau provincial: Les provinces sont organisées en Services Provinciaux des Ressources Animales SPRA et Services Provinciaux de l'Agriculture SPA.

Le niveau régional: Le niveau régional est constitué par les Centres Régionaux de Promotion Agro-Pastorale (CRPA), ils comportent 1 à 3 provinces et sont placés sous la responsabilité d'un Directeur. Le CRPA assure la programmation, l'exécution et le suivi des programmes de vulgarisation.

Le niveau national: Le niveau national est constitué par la Direction de la Vulgarisation Agricole qui assure la coordination des activités et l'appui technique aux structures régionales de vulgarisation en matière de mise en oeuvre de système et de méthodes de vulgarisation.

C) Les outils de vulgarisation ou sites de démonstration utilisés

La vulgarisation des thèmes techniques s'effectue à l'aide de plusieurs outils pédagogiques parmi lesquels on retiendra :
- Le champ-école
- la micro-parcelle

- le troupeau-test
- l'activité de travaux de groupe (ATG): séance de démonstration ou d'information
- l'activité de suivi-visite des exploitations
- les unités économiques individuelles ou communautaires
- les expériences paysannes et de recherche/développement.

D) Fonctionnement du système et processus de prise de décision

Le système fonctionne sur la base de programme et de calendriers souples qui tiennent compte de besoins et contraintes agro-économiques des producteurs de chaque UEA. Le choix raisonné des thèmes à vulgariser tient compte :

- des besoins des agriculteurs et de leurs capacités d'appliquer les conseils
- des réalités physiques et socio-culturelles du milieu
- de l'existence au niveau de la recherche agricole de solutions aux problèmes identifiés
- du savoir et des 'savoir-faire' paysans
- des orientations nationales en matière de développement agricole

Le système favorise les concertations permanentes entre les différents niveaux du réseau d'encadrement, à travers des rencontres périodiques: réunions mensuelles, ateliers... Le fonctionnement du SNVA s'articule essentiellement sur la programmation des activités, les formations des producteurs et des agents et l'établissement de liaison appropriée entre la recherche, la vulgarisation et les producteurs encadrés.

D1) La programmation

La programmation des activités de vulgarisation est ascendante et commence au niveau de l'UEA pour remonter suivant les différents échelons du réseau d'encadrement jusqu'au niveau national.

Niveau UEA: Les activités sont programmées sur la base des résultats du diagnostic, fait par le vulgarisateur de base et les producteurs des groupes de travail ou des groupements villageois dans les exploitations.

Suite à l'analyse des données des enquêtes diagnostiques, les thèmes à vulgariser sont choisis par l'agent vulgarisateur et les producteurs qui fixent un calendrier et le lieu de rencontre pour les formations techniques. Les chefs de zones (superviseurs) et les Techniciens Spécialisés (T.S.) apportent un appui technique à l'AVB dans la programmation.

Aux autres échelons du réseau: Chaque échelon du réseau d'encadrement analyse et fait la synthèse des activités proposées par le niveau inférieur et établit son programme. Ce processus conduit à l'élaboration du programme de vulgarisation du CPRA.

Programme national de vulgarisation: La Direction de la Vulgarisation Agricole organise avec les CRPA des ateliers régionaux d'évaluation et de programmation à l'issue desquels un programme national de vulgarisation est élaboré à partir de la synthèse des programmes régionaux.

D2) La Formation

Avec un rôle de conception, les CRPA sont chargés principalement de la mise en oeuvre du programme de vulgarisation. La formation constitue donc une activité importante dans les activités de vulgarisation. Le SNVA utilise deux types de formation tant pour les agents vulgarisateurs que pour les producteurs. Les thèmes de formation des agents découlent des besoins en conseils techniques des producteurs.

Formation continue: - Les techniciens spécialisés sont formés à travers les Ateliers Mensuels de Revue de Technologie (AMRT) par les chercheurs ou des personnes ressources. Les AMRT se déroulent sur le terrain et en salle. L'atelier dure deux jours. Une fiche technique est élaborée par les participants et le formateur à chaque atelier.

- Les superviseurs (chefs de zone d'encadrement) et les vulgarisateurs de base (chefs d'unités d'encadrement) sont formés par les T.S. une fois tous les quinze jours. Ces formations privilégient l'aspect pratique et peuvent se dérouler sur une exploitation ou dans les points d'appui de prévulgarisation et d'essais multilocaux (PAPEM).

- La formation continue des producteurs consiste à la démonstration des thèmes techniques au niveau des troupeaux ou des parcelles de démonstration individuels ou collectifs. Tout autre outil (unités économiques) adapté peut être utilisé à cet effet.

Formation spécifique-recyclage: Des formations spécifiques ou des recyclages sont organisés après identification des besoins en formation des agents et des producteurs. Les thèmes ou sujets traités visent l'amélioration du professionnalisme des agents de la vulgarisation ou des producteurs.

Les formations continues et spécifiques des producteurs et des agents sont renforcées par les activités de suivi et de visites des exploitations, les visites commentées et les journées de démonstration au niveau des PAPEM ou des tests en milieu paysan.

D3) La Recherche-Développement

Elle permet d'apporter des réponses aux contraintes de production diagnostiquées par les agents et les producteurs suite à des tests, essais et exploitations des solutions locales.

D4) La communication et l'utilisation de moyens audio-visuels

Elles viennent en appui aux activités de formation et démonstration, afin d'améliorer ou de provoquer l'adoption des technologies.

D5) Le Suivi-Evaluation

Le suivi et l'évaluation des programmes et activités constituent un des éléments clés du système de vulgarisation. Il est mis en oeuvre sur l'ensemble des CRPA et permet de suivre les progrès réalisés dans les différentes activités, de mesurer l'utilisation des services par les producteurs, et d'expliquer leurs réactions en vue d'évaluer les effets de la vulgarisation. Ce faisant, il devait permettre à tout moment de réajuster ou

réorienter les activités de vulgarisation en fonction des résultats obtenus et des contraintes rencontrées.
La collecte des données se fait essentiellement par voie d'enregistrement administratif. Des fiches de collecte d'information sont ventilées à tous les niveaux du réseau d'encadrement. Les principaux indicateurs utilisés pour l'évaluation sont :

- Taux de réalisation des outils de vulgarisation
- Taux de participation des producteurs aux séances de vulgarisation
- Taux d'encadrement
- Ratio d'encadrement
- Taux d'adoption ou d'application des thèmes vulgarisés.

E) La liaison entre la recherche la vulgarisation et les producteurs

La liaison entre la recherche et la vulgarisation est un facteur important pour la réussite des programmes de vulgarisation et de recherche agricole. Dans ce cadre, les système nationaux de recherche et de vulgarisation du Burkina ont prévu des mécanismes et des outils. Il s'agit essentiellement :

Niveau vulgarisation:
- Création d'un bureau Recherche-Développement au sein du Service Formation /Vulgarisation de la DVA.
- Création d'un bureau Recherche-Développement dans les CRPA.
- La mise en place des PAPEM (point d'appui à la prévulgarisation et d'essais multilocaux).

Le mécanisme consiste en la participation de la Recherche aux instances d'évaluation et de programmation des activités de vulgarisation agricole et au conseil d'administration des CRPA et à la formation des Techniciens Spécialisés par les chercheurs à travers les Ateliers Mensuels de Revue de Technologies.

Niveau Recherche:
- Mise en place d'un programme de recherche sur les systèmes de production (RSP) et l'implantation des villages sites RSP dans différentes régions.
- La création des Centres Régionaux de Recherche Agricole (CRRA).

Le mécanisme consiste en la participation de la vulgarisation à toutes les instances d'évaluation et de programmation de la recherche (Comité Techniques, Commission des programmes et Conseils de gestion).

En outre quelquefois, les chercheurs collaborent avec les CRPA pour l'élaboration et l'exécution des activités de recherche-développement (Etablissement des Protocoles, Visites d'appui sur le terrain, interprétation et exploitation des résultats).

Enfin, l'Institut National d'Etudes et de Recherches Agricoles (INERA), au même titre que la DVA présente un rapport d'évaluation et de programmation des activités de recherche-développement à tous les ateliers ci-dessus énoncés.

Malgré la mise en oeuvre de ces différents mécanismes, la liaison Recherche-Vulgarisation - Producteurs demeure faible et peu fonctionnelle surtout au niveau paysan. On relève essentiellement deux lacunes majeures à savoir : (1) les insuffisances dans l'identification des contraintes de production devant faire l'objet de thème de recherche, et (2) une faible implication des producteurs dans la conduite des expérimentations.

Principaux, Acquis et Insuffisances du SNVA

L'adoption et la mise en œuvre d'un système unifié de vulgarisation agricole au Burkina Faso depuis a permis d'enregistrer des acquis importants à différents niveaux.

A) Principaux acquis

Sur le plan organisationnel: La mise en oeuvre du système national de vulgarisation a été accompagnée de la mise en place ou de la dynamisation de structures fonctionnelles d'encadrement agricole tant au plan national que décentralisé.

La structuration et l'organisation du réseau est uniforme sur l'ensemble du Pays. On compte actuellement 900 unités d'encadrement, 400 zones d'encadrement, 30 services provinciaux CRPA, et une Direction de la Vulgarisation Agricole. On note également l'augmentation progressive du nombre de villages, de producteurs et d'exploitations touchés par l'encadrement. Ainsi en moyenne 30 % des exploitations, 27 % des producteurs et 70 % des villages sont actuellement encadrés. Enfin, l'organisation actuelle du réseau favorise une meilleure utilisation du personnel de vulgarisation (meilleure gestion du calendrier de l'agent vulgarisateur de base (AVB), meilleure répartition des AVB sur le territoire national).

Au plan de la fonctionnalité: Le système national de vulgarisation au regard de ses objectifs initiaux a enregistré des acquis notables liés à son fonctionnement et à son impact économique. En effet, le SNVA favorise actuellement la programmation systématique de toutes les activités de vulgarisation à différents niveau du réseau d'encadrement ce qui facilite l'élaboration d'un calendrier de travail pour les principaux acteurs (producteurs, vulgarisateurs, superviseurs, techniciens supérieurs).

Par ailleurs, la formation et la régularisation des liens Recherche-Vulgarisation se sont accrues et améliorées favorisant ainsi l'augmentation significative du nombre d'essais et de tests en milieu paysan.
Enfin, tout cela se traduit par l'amélioration du niveau de technicité des producteurs grâce à l'adoption progressive et plus accrue des principaux thèmes notamment ceux relatifs à la conservation et la restauration de ressources naturelles. Il s'en suit une augmentation sensible des rendements agricoles estimée entre 20 à 30 % pour les céréales (Evenson, 1991).

Sur le plan et administratif: Le SNVA offre une meilleure opportunité de gestion des activités par une maîtrise plus aisée de la budgétisation des activités de vulgarisation à tous les niveaux ce qui facilite une connaissance des coûts permettant d'établir un rapprochement plus objectif entre les coûts et les résultats obtenus (Evenson, 1991).
Malgré ces acquis importants plusieurs contraintes entravent la bonne exécution des

activités de vulgarisation agricole limitant ainsi le taux d'adoption ou de transfert des technologies en milieu paysan.

B) Principales contraintes de transfert des technologies

Le processus de vulgarisation: Il y a parfois une inadéquation des thèmes techniques vulgarisés due à l'insuffisance de la participation des producteurs au diagnostic. Malgré la programmation participative engagée, certaines insuffisances existent quant au recensement et à la valorisation du savoir et du savoir-faire paysan. Par conséquent, le système de vulgarisation n'exploite pas encore optimalement les ressources humaines disponibles (connaissances paysannes, formation producteur à producteur).

Liens avec la recherche: Malgré une amélioration significative de la liaison recherche-vulgarisation ces dernières années, il y a une insuffisance de la présence des chercheurs agricoles en milieu réel. Cela limite le diagnostic des contraintes de production.

Accès au crédit agricole: Les difficultés d'accès des petits producteurs au crédit agricole limitent le rythme de l'adoption des techniques nécessitant un minimum d'investissement.

Thème de vulgarisation: Les technologies offertes actuellement ne préconisent pas toujours la valorisation de toutes les ressources naturelles à portée du producteur. Cela mène à une sous-utilisation des ressources au niveau du producteur. Ces technologies vulgarisées ne sont pas parfois à la portée des petits exploitants. La vulgarisation en élevage demeure peu développée à cause de l'insuffisance des résultats de recherche en matière de productions animales.

Aspects généraux: En tant que structure de conception, la Direction de la Vulgarisation Agricole a une insuffisance de connaissance des activités des ONG au Burkina Faso. Cette situation limite le faisceau d'échanges d'expériences sur les méthodes de transfert de technologies appropriées ayant fait leur preuve de réussite même si c'est à une échelle réduite.

Toutefois ces insuffisances et faiblesses ont déjà fait l'objet d'examen au cours de différents ateliers nationaux. Des mesures correctives sont en cours, toutefois des perspectives à court, moyen terme sont envisagées.

Quelques Résultats et Analyse Critique

A) Quelques Résultats

Les ratios d'encadrement: Les ratios d'encadrement sont le nombre de villages d'exploitations ou de producteurs effectivement encadrés par un agent de vulgarisation de base.

Au Burkina Faso, les normes d'efficacité fixés sont:

- Ratio d'encadrement des villages (REV): 8 villages par agent.

- Ratio d'encadrement des exploitations (REE): 500 exploitations par agent.
- Ratio d'encadrement des Producteurs (REP): 4.000 Producteurs par agent.

L'ensemble des CRPA présente actuellement les ratios suivants :

REV = 6 villages par agent
REE = 243 exploitations par agent
REP = 984 producteurs par agent.

L'analyse des ratios des quatre dernières années laisse apparaître malgré l'uniformité du système, une diversité relative par CRPA. Même dans l'ensemble les ratios ont demeuré identiques et peu fluctuants. Cela soulève la question de la charge de travail réelle de l'agent et la nécessité d'opérer des réajustements pour toucher le maximum de producteurs.

Les taux d'encadrement: Les taux ont été durant la campagne 94/95 de 66 % pour les villages, 27 % pour les exploitations et 25 % pour les producteurs.

Les taux d'adoption des thèmes: Le taux d'adoption relatif des thèmes (TAR) est considéré comme la proportion des producteurs ayant adopté un thème technique donné par rapport au nombre de producteurs encadrés sur le thème. Au Burkina Faso, en moyenne 22 thèmes techniques ont été vulgarisés en 94/95 et ont fait l'objet de suivi-évaluation. L'analyse des taux d'adoption des thèmes revèle une progression significative ces dernières années. Ce qui traduit sans doute un niveau d'adoption des thèmes croissant. Les thèmes les plus adoptés sont le démarriage (69 %), l'utilisation de la fumure organique (55 %), etc...

Malgré les résultats intéressants obtenus, le constat est que très peu de thèmes ont un taux d'adoption élevé. Cela s'expliquerait par plusieurs raisons. Pour que les conseils de vulgarisation soient acceptables par les utilisateurs, ils doivent tenir compte des préoccupations prioritaires des paysans c'est-à-dire leurs problèmes, leurs besoins, les opportunités et les aléas de leur vie quotidienne que l'on peut découvrir par l'analyse de décision ethno-scientifique (Gladwin, 1984).

C'est situer l'importance du diagnostic des contraintes et de la formation des solutions techniques. Par ailleurs, le coût de l'investissement de certaines innovations limitent leur adoption par les petits exploitants surtout quand il n'existe pas un système de crédit agricole approprié.

B) Analyse critique et discussion

Malgré les efforts des services de vulgarisation agricole les résultats obtenus sont restés mitigés au regard des moyens déployés.

D'une manière générale la raison essentielle des difficultés est que les analystes et les techniciens effectuent leur travail en fonction de leur mode de raisonnement ainsi que de leurs solutions de prédilection pour un problème donné (MORRIS, 1991). Aussi, il existerait une notion profondément incrustée qui veut que le développement scientifique d'une technologie respecte une progression rigoureuse transposée sur le terrain sous la forme de recherche appliquée et enfin affinée en collaboration avec les clients au moyen de la recherche adaptative (Morris, 1992).

Au Burkina Faso, l'analyse des résultats de la vulgarisation fondée sur les ratios d'encadrement des villages, des exploitations et des producteurs et les taux d'adoption des thèmes techniques montre un faible passage des thèmes vulgarisés et des technologies existantes au milieu paysan.

Cela pose le problème fondamental de la conception actuelle du mécanisme de génération et de diffusion des technologies (PRSAP II, Document de base).

Par ailleurs la question des liens fonctionnels dynamiques et une inter-action efficace entre la recherche, la vulgarisation et les producteurs demeure posée. En effet, face à l'expertise paysanne, ou savoir et 'savoir-faire paysans' actuels, les théories de 'Diffusion des innovations' ou de 'Transfert de technologies' deviennent optimistes parce que convaincus de detenir tout le savoir scientifique qu'il s'agit de transférer des chercheurs aux paysans (Bado, 1994).

Si donc on peut considérer que la vulgarisation agricole est un pont entre la recherche et les agriculteurs, il ne doit cependant pas être à sens unique, car c'est aussi un moyen de communication des connaissances, des problèmes et des expériences des agriculteurs vers la recherche (Axters, 1980). C'est pourquoi il se pose donc, la nécessité de mieux ajuster le rôle de la recherche et de la vulgarisation dans le développement de technologies.

Dans le cas du SNVA du Burkina Faso, l'option stratégique de renforcement du processus de génération et diffusion des innovations se fondera désormais sur les éléments clés suivants.

- L'élaboration et l'introduction de méthodes participatives de diagnostic.

- La conception et la génération de technologies et l'adaptation de technologies extérieures au milieu par les paysans à travers leur propre expérience et l'expérimentation basée sur des critères paysans.

Pour ce faire, le producteur devra être effectivement, le point focal de l'encadrement depuis l'identification des contraintes, la formation des thèmes jusqu'au conseils relatifs à son exploitation (agriculture, élevage, gestion des ressources naturelles...) et à son environnement socio-économique (Structure de prix, organisation paysanne) (PRSAP II, Document de base 1995). Cela nous semble une voie possible pour renforcer l'interface et l'interaction chercheurs-vulgarisateurs-producteurs dans le processus de transfert et de diffusion des technologies en milieu rural.

Perspectives

Afin de renforcer les acquis actuels de la vulgarisation, les actions suivantes sont en cours pour lever les contraintes ci-dessus citées :

- Formation des agents à la méthodologie du développement participatif de technologies.
- Elaboration d'une stratégie de vulgarisation adaptée à l'élevage.
- Réajustement des programmes quotidiens des agents en fonction des nouvelles préoccupations de producteurs.
- Renforcement des actions en vue d'une meilleure connaissance des activités agricoles des femmes et l'élaboration de programme d'appui et de formation adaptés à leurs besoins.
- Formation de tous les agents à l'approche gestion des terroirs.
- Renforcement de la collaboration avec les ONG et les projets de développement dans la conduite des activités de vulgarisation.
- L'élaboration de fiches techniques pour aider les agents dans l'utilisation de certains outils de vulgarisation.

Conclusion

La mise en oeuvre du système national de vulgarisation traduit l'engagement des autorités burkinabè sur l'importance de la vulgarisation en tant que fonction déterminante du développement agricole. L'application des principes d'organisation rationnelle du réseau d'encadrement, de la programmation systématique des activités à partir de la base, de la formation continue et spécifique, de la liaison dynamique avec la recherche et du suivi-évaluation ont permis malgré les contraintes citées plus haut l'amélioration du niveau de technicité des producteurs et des capacités professionnelles des agents de vulgarisation.

Toutefois plusieurs constats et questions fondamentales se posent aujourd'hui tant au niveau du Burkina Faso, que dans l'ensemble des services de vulgarisation agricole de la sous-région. Au titre de ces préoccupations, les questions suivantes méritent d'être posées :

1. Il existe plusieurs résultats de la recherche sur les productions végétales et animales avec des niveaux de transfert des innovations/résultats faibles qui n'ont pas permis d'améliorer significativement la productivité agricole. Aussi il se pose la question de savoir comment assurer un meilleur et efficace transfert de ces technologies.

2. Quels sont les voies et moyens pour capitaliser et valoriser davantage le savoir et le 'savoir-faire' des paysans ?

3. Comment mieux adapter les technologies aux réalités socio-économiques des producteurs ?

La recherche de solutions à ces questions pertinentes devrait aider à mieux ajuster le rôle de la recherche et de la vulgarisation agricole dans le processus de transfert de technologies agricoles dans notre pays.

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Research-Extension-Input Linkage System in Nigeria

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Abstract

The research-extension-input linkage in Nigeria has gone through several stages of metamorphosis. Initial attempts started with the establishment of the link between research and extension provided by the Agricultural Research Liaison Services (AERLS). The National Accelerated Food Production Project (NAFPP) launched in 1974 had some input-extension linkage component. Several faculties of agriculture initiated projects that brought researchers into direct contact with the extension staff. All these fizzled out as a result of financial constraints.

A new dynamism was injected into the research-extension-input linkage when the extension was reorganized along the Training and Visit (T&V) system. On-farm adaptive research (OFAR), and monthly technology review meetings (MTRMs) were introduced and involved several institutions including the research institutes, universities. ADPs and FACU. With the World Bank support to research institutes through the National Agricultural Research Project (NARP), ways and means of removing the constraints working against the sustainability of the linkage system are being sought.

Résumé

La liaison recherche-vulgarisation-intrant au Nigéria a traversé plusieurs stades de métamorphose. Les premières tentatives ont consisté à établir la liaison entre la recherche et la vulgarisation assurées par les Services de Liaison de la Recherche Agricole (AERLS). Le Projet National de Production Vivrière Accélérée (NAFPP) lancé en 1974 comportait un volet de liaison intrant-vulgarisation. Plusieurs facultés d'agriculture ont initié des projets qui ont mis les chercheurs en contact direct avec le personnel de vulgarisation. Tous ces efforts sont tombés à l'eau en raison de contraintes financières.

Un nouveau dynamisme a été imprimé à la liaison recherche-vulgarisation-intrant, lorsque la vulgarisation a été réorganisée sous la forme du système de Formation et Visite (T & V). Les réunions d'évaluation mensuelles de technologies (MTRM) de la recherche adaptative en milieu paysan (OFAR) ont été introduites pour impliquer plusieurs institutions dont les instituts de recherche, les universités, les PDA et la FACU.

Grâce à l'appui de la Banque Mondiale aux instituts de recherche par le canal du Projet National de Recherche Agricole (NARP), les voies et moyens permettant de lever les contraintes au développement d'un système de liaison durable sont présentement recherchés.

Introduction

Agricultural research in Nigeria began in 1893 with the establishment of a botanical research station in Lagos. In 1921, a Department of Agriculture, which was given research and extension responsibility, was created. During the colonial era, regional West African export commodity-based research institutes were established. These were later converted into national research institutes in 1964. By 1974, the number of agricultural research institutes grew from nine to eighteen.

In addition to these research institutes, Nigeria is blessed with 25 faculties of agriculture. Agricultural research is therefore scattered in the various institutes and universities. Hence, institutional arrangements, regarding management of agricultural research, have always faced frequent changes. The Nigerian Council for Science and Technology, created in 1970, was replaced by the Agricultural Research Council of Nigeria in 1971. In 1973, the Agricultural Research Institute Decree vested power to establish agricultural research and training institutes in the Federal Commissioner of Agriculture, who also had power to take over any existing research stations. The National Science and Technology Development Agency (NSTDA) was set up to coordinate all research in Nigeria, agricultural and non-agricultural. The 1979 Federal constitution again placed agricultural research on the concurrent list of state and federal government and, by the Federal Ministry of Science and Technology (FMST) Act of that year, NSTDA was scrapped. In 1984, the FMST was merged with the Federal Ministry of Education while the 1979 constitution was suspended. One year later, the FMST was resurrected. Thus, between 1980 and 1991, the national agricultural research institutes were under the FMST while the university faculties of agriculture are responsible to the Federal Ministry of Education. The national agricultural research institutes were again reverted to the Ministry of Agriculture in 1993.

Past Experiences in Research-Extension Linkages

Some of the institutes in Nigeria have attempted to establish a link between research and extension by setting up agricultural extension and research liaison services (AERLS). Essentially, the AERLS reduce research findings to a format that is usable by extension and train extension staff. In this regard, the AERLS of IAR, Zaria had done commendable work and provided useful support to the northern ADPs. However, one shortcoming of the AERLS arrangement is that it lengthens the chain between actual researchers and the extension staff and could dampen the responsiveness of research to actual farmers' problems.

The NAFPP, launched by the Federal Military Government in 1974, had research, extension and input components and was aimed at developing technologies relevant to the needs of the farmers in six basic food crops. Research findings were tested in specific ecological niches and farmers were involved in the observation phase, i.e., the mini-kit trials, as well as production kits, which were administered by the extension personnel of the state ministries of agriculture. At the mass adoption stage, the extension personnel prepared annual plans for each village, indicating crop production targets, and coordinated input distribution. Through the farmer contact strategy, progressive farmers were selected for the various kits. However, the production kit packages tended to fit the requirements of large scale farmers and did not initially take into account the mixed farming practices of the small farmers. The programme, though still in operation, is faced with financial constraints and poor mobility of staff. Cropping scheme meetings organized by several research institutes in the country, either on an annual (e.g., IAR) or bi-annual (e.g., IAR&T) basis, provide a useful forum wherein active participation of research and extension personnel, working within a region, takes place. At these meetings, following a review of latest research findings and discussion sessions, recommended packages for production of important crops grown in the region are developed or updated.

Several faculties of agriculture have also attempted to forge research-extension linkages through special programmes. In this context, mention can be made of: (i) the Zaria Rural Guided Change Project started in 1965 by the Ahmadu Bello University, (ii) The Isoya Rural Development Project of Obafemi Awolowo University initiated in 1972, (iii) the Badeku Rural Development Project of University of Ibadan launched in 1972; and (iv) Okpuje Rural Development Project of University of Nigeria. These projects obtained varying degrees of success in bringing researchers of diverse disciplines into direct contact with the extension staff and in improving the agricultural productivity of the beneficiary villages. But, like many other programmes in the country, they have almost all fizzled out, as a result of financial constraints, and declining enthusiasm. Moreover, since the programmes were ad-hoc in nature, the research and extension systems have already lost most of the lessons that could have been learnt from a more institutionalised programme.

Present Trends in Research-Extension-Input Linkages

One important aspect of reorganising and strengthening the extension services of the ADPs in the country on Training and Visit Extension lines has been an attempt to develop strong and lasting research-extension-input linkages. Thus, in addition to fully utilising and promoting the existing linkages, such as those offered by AERLS and cropping scheme meetings, the ADPs have attempted to foster linkages from two angles. These are:

(i) On-farm adaptive research (OFAR) which is a farmer-oriented, problem-solving approach to research; and
(ii) Monthly Technology Review Meetings (MTRMs), an essential component of the T & V system of extension.

The origins of OFAR in Nigeria dated back to 1982 when the Ministry of Education, Science and Technology set up a National Working Committee to work out a Farming Systems Research and Extension strategy for the country. Subsequently, a national steering committee was constituted for co-ordinating the farming systems research and extension activities in the country. The Federal Agricultural Coordinating Unit (FACU), at the committee's invitation, presented an acceptable suggestion for developing close collaboration between research institutes/universities and ADPs through OFAR which is a component activity of farming systems research. Several pilot OFAR programs, supported by FACU during 1983-85, proved beyond reasonable doubt that effective linkages can be built between research and extension through OFAR, leading to significant improvements in the conduct of adaptive research and the development of relevant farm technologies.

The following are the brief outlines (prepared following a series of consultations with relevant research institutes, universities, state Ministries of Agriculture and ADPs in collaboration with the National Farming Systems Research Network) of OFAR and MTRM, as presently being executed in the ADPs.

OFAR has the following objectives:

- To fully characterize major farming systems and client groups, identify production constraints and prioritize areas of research.
- To identify promising technologies developed by research institutes and universities to address the identified constraints.
- To ascertain, through trials on farmers' fields, and with full farmers' involvement, the technical feasibility, economic profitability, and social acceptability of promising technologies generated by the institutions. Where such technologies do not exist, to encourage institutions to conduct research on them.
- To monitor the constraints to farmer adoption of the technologies in order to improve adoption.

For nation-wide implementation of OFAR, the ADPs were put into five zones corresponding with those of the National Farming Systems Research Network. The collaborating institutions and FACU regional offices are indicated in Table 1. The activities in each zone are coordinated by a national agricultural research institute which provides a zonal coordinator for OFAR in the ADPs. To ensure the attainment of OFAR objectives, the following broad responsibilities were assigned to each of the collaborating institutions.

Table 1. Collaborating institutions of OFAR/MTRM in Nigeria.

Zone	Coordinating institute	States/ADPs covered	Other collaborating institutions*
South-East	National RootA-bia, Crops Research Institute (NRCRI) Umudike, Umnahia	Akwa-Ibom, Anambra, Enugu, Cross River, Imo, Rivers	Univ. of Nigeria; Imo State Univ.; FUT, Owerri; Univ. of Calabar; Univ. of Cross River; RSUST port Harcourt; Univ. of Agric, Umudike; FACU, Enugu; and NAERLS.
South-West	Institute of Agric Research and Training (IAR&T), Ibadan	Lagos, Ondo, Ogun, Oyo, Edo, Osun, Delta	U.I., Ibadan; OAU, Ife; UNIBEN.; Lagos State College of Technology; Ogun State Univ.; FUT Akure; NIHORT; Univ. of Agric.; Abeokuta; NIFOR; FACU, Ibadan; and NAERLS.

FUT = Federal University of Technology; RSUST = Rivers State University of Science and Technology; NIFOR = Nigerian Institute for Oil-Palm Research; NAERLS = National Agricultural Research Liaison Services; and NAPRI = National Animal Production Research Institute.

Zone	Coordinating institute	States/ADPs covered	Other collaborating institutions
Middle-Belt	National Cereals Research Institute (NCRI), Badeggi	Benue, Kwara, Niger, Plateau Kogi, FCT	Univ. of Agric. Makurudi; UNILORIN; UNIJOS; Benue State Univ.; NRCRI, Vom; FACU Kaduna; FACU, Benin; FACU, Jos; and NAERLS.
North-East	Lake Chad Research Inst. (LCRI), Maiduguri.	Borno, Yobe, Adamawa, Taraba	Univ. of Maiduguri ; FUT Yola; FACU, Jos; and NAERLS
North-West	Insti. for Agric Research (IAR), Samaru, Zaria.	Kaduna, Kano, Jigawa, Kebbi, Katsina Sokoto Bauchi.	NAERLS, Zaria; NAPRI, Shika; ABU, Zaria; UDFU, Sokoto; FACU, Kaduna; and FACU, Jos.

The co-ordinating zonal agricultural research institute has the following functions:

(a) To provide the Zonal Coordinator for all OFAR activities in the zone. The Zonal Coordinator may appoint representatives to the respective ADP OFAR teams.
(b) To provide technical support and relevant back-up training for subject-matter-specialists (SMSs) of the ADPs.
(c) In collaboration with FACU and ADPs, to design, implement, and monitor research extension and training projects of the ADPs, as mutually agreed by the Institute, the ADP and FACU, and
(d) To make available promptly all relevant research results to assist ADP officials in the implementation of project activities.

On their part, the collaborating universities and research institutes:

- Provide leadership for ADP OFAR teams, under the overall leadership of the Zonal Coordinator, and
- Collaborate with NARI, in the discharge of responsibilities (b) to (d) above.

The Agricultural Development Project (ADP) has many functions which include:

- Providing the financial resources for OFAR, as agreed in the budget for the OFAR project.
- To provide transportation for the OFAR team and for successful implementation of the OFAR project.
- To provide facilitating assistance to the OFAR team in the form of letters of introduction, contact with villages, relevant maps and data.
- Provision of staff and space for trials (on-station, on-farm and small plot) agreed upon and ensure the conduct and supervision of such trials either on-station, or on-farm.

- Where training is involved, to provide materials and allowances for the resource persons required.

The Federal Agricultural Coordinating Unit (FACU), is required to:

(i) Link up the collaborating institutions in OFAR and facilitate the implementation of agreed activities;
(ii) In collaboration with Zonal Coordinating Institute and ADP, design, implement and monitor research, extension, and training projects as mutually agreed upon by the collaborating institutions;
(iii) Arrange meetings and workshops to review pre-season and end-of-season OFAR activities;
(iv) Assist ADPs, where necessary, by augmenting limiting resources;
(v) Assist in publication of reports and information generated through OFAR activities; and
(vi) Finalize annual OFAR budget proposals for consideration by the ADP management.

The OFAR team for the ADP consists of the OFAR zonal coordinator, the OFAR team leader, the chief research and extension officers of the ADP, and the Agricultural Research Coordinator of FACU, and is complemented, as necessary, by other scientists so as to represent in the team expertise in the fields of crop and animal production and protection, soil science, agricultural economics and agricultural extension. The function of this team is to plan, monitor, and evaluate OFAR trials, as well as to formulate production recommendations.
The actual execution of trials is under the control of the Chief Research Officer of the ADP, and is the primary responsibility of the ADP Zonal Research Officer, assisted by the SMSs and the technical staff of the ADP and of the research institutes and universities.

OFAR may be implemented through the following stages:

. Diagnosis/problem identification and trial planning;
. On-station research;
. On-farm research; and
. Mass adoption through extension.

Table 2 summarizes the activities and processes in OFAR. The MTRM is an important and integral component of the T&V system and provides an effective research extension linkage through:

(i) continuous and regular upgrading of the technical know-how of the ADP SMSs;
(ii) continuous and regular updating of the research scientists' knowledge of their farming environment and farmer's problems;
(iii) joint development and/or modifications of production recommendations;
(iv) joint field visits to regularly study the prevailing farming systems;
(v) joint planning and regular review of OFAR;
(vi) formulation of low-cost, low-risk technologies for farmers with poor resource base; and

(vii) encouraging farmers to adopt technologies through the use of small extension plots.

Table 2. Detailed activities and processes of on-farm adaptive research.

Activity	Process
(i) **Research Planning and Design**	
(a) Identification, definition and prioritization of problems and opportunities	Monthly technology review meetings; field visits and diagnostic surveys.
(b) Identification and listing of probable and possible solutions to commonly defined problems	Inventory of technologies.
(c) Selection, formulation and design (including costing) of on-farm and on-station trials.	Review and planning workshops.
(d) Release of approved fund to research institute	Communication.
(ii) **Experimentation**	
(a) Execution of trials (on-farm and on-station)	Trials on farmers' field, field station and multilocational trials.
(b) Monitoring of trials	Joint supervisory site visits, monthly and quarterly reports, mid-year review and planning workshop.
(c) Trials' data analysis	Annual review and planning workshop.
(d) Review of trials and formulation of recommendations	Processing of data.
(e) Adoption trials (small plot)	Small plots in several farmers' fields in different locations.
(iii) **Training**	
(a) Identification of training needs, and training institutions	Annual work plan.
(b) Training proposals, resourcing and implementation.	Training
	(i) MTRMS
(c) Training, e.g., of subject matter specialists and research officers	(ii) Special short courses (iii) Orientation training.

The participants in the MTRM include the OFAR team of scientists, senior ADP research and extension officers, the SMSs and a representative of the Commercial Section of the ADP. The OFAR team leader is normally the coordinator of the MTRM and the venue could be the research institute, university, and ADP headquarters.

Monthly workshops, on the one hand, build up the technical skills of the SMSs and in the process enable them to meet effectively the technological requirements of the farmers through the extension agents. On the other hand, the MTRMs are also an important point of contact between extension and research. Through feedback, discussions and dialogue, the reactions of the farmers to recommendations are known. Thus, the MTRMs are helpful, both to research and extension. The basic agenda for the MTRM has been developed as suggested by Benor and Baxter (1984).

The salient features of the emerging linkage mechanisms at the ADP level in Nigeria are presented in Fig. 1 with research extension and input supply agencies as the main components in the collaborative effort to raise farm and farmer productivity. The box identified as "Farmers' Fields" represents the end products of the process involved and includes technologies adopted, or under test, by progressive farmers, as well as the use of purchased inputs and farmer perceived areas needing intervention.
The solid arrows depict formal and systematic linkages while broken arrows are used to indicate casual or informal linkages.

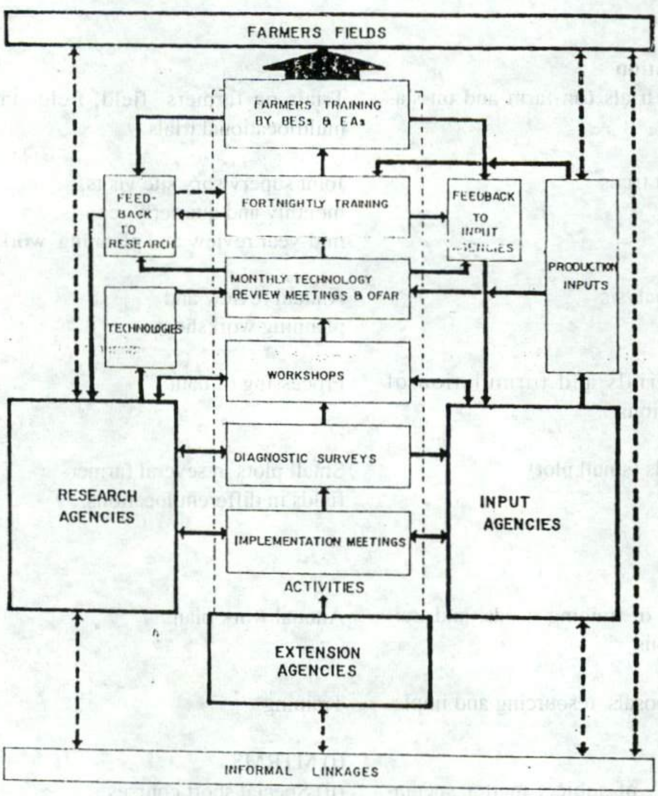

Figure 1. Conceptual model of research - Extension - Input distribution linkages for the nigerian agricultural development projects.

Sponsored Research

Following encouraging results arising from the strengthened research-extension linkages, and keeping in view the current funding problems of the research institutes in the country, the newer ADPs in the country are making necessary financial provisions for sponsored research. The idea here is to support multi-disciplinary teams of researchers to find solutions to carefully selected priority problems identified during MTRMs and zonal workshops by extension agencies working in the field and OFAR scientists. It is envisaged that such research will involve a combination of on-station investigations and laboratory support spanning 2 to 3 years and will have a high probability of achieving positive results.

Future Prospects of Research-Extension Linkages

The present research-extension linkage being implemented all over Nigeria has started yielding some benefits. Over 20 diagnostic studies have been carried out in the existing ADPs in the country by multi-disciplinary teams of scientists and extension officials. Also, regular joint field visits and MTRMs provide additional information on the farm environment. Productive pressure is now being mounted on researchers by extension staff to find solutions to actual farming problems.

The future trend of these established linkages will depend on whether some problems currently being faced can be solved. The problems include:

(i) Lack of avenues for promoting research scientists' who participate in such collaborative research work;
(ii) Lack of adequately trained manpower in some areas to conduct meaningful OFAR and MTRMs;
(iii) Lack of adequate scientific base of some of the zonal research institutes; and
(iv) Lack of formal institutionalization of the research-extension linkages.

For the continuous upgrading of the linkage mechanisms and provision of steady source of funding for their sustainability, it is necessary to institutionalize the linkages. An appropriate organizational structure, the National Agricultural Research Project (NARP), has been established through the assistance of the World Bank. Through NARP, the research institutes are being funded to conduct more effective research intended to satisfy the interest being pursued by the ADPs. The research-extension-input linkage is also strengthened. The problems enumerated are currently being tackled by NARP to ensure a lasting linkage system by the end of NARP's life span. The research-extension-input linkage system is part of the national strategic agricultural plan being currently formulated.

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The Significance of Gender in Seed Transfer Patterns Among Farmers in South-East Ghana

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Abstract

For many decades agricultural policies in Ghana represented women as 'part-time farmers' rather than farmers in their own right. They were commonly viewed as farmers' wives whose main task was to provide family labour. This perspective of course has changed considerably in the last decade, and has been replaced by a realistic image of women as farmers; it is now widely acknowledged that women produce between 25 percent to 50 percent or more of food crops in Ghana, depending on the area. In many African countries this led to policy instruments intended to empower women farmers. But the concrete expression given to these instruments have not yet taken root, as a result of which the technologies of significance to women farmers remain largely outside mainstream agricultural research and development. The paper addresses non-formal channels of transfer and experimentation in seed technologies, among women food crop farmers in parts of south-east Ghana. It further looks at the conditions under which women adopt new seed technologies, and the implications for agricultural policy in Ghana. Constraints which directly inhibit women from adopting improved seed varieties is also given attention. The data that are used form part of a study conducted in the Dangme West and Dangme East districts, as well as North Tongu District. Focus group interviews and individual interviews were conducted with a total of about 100 women, and as many men. It is expected that the paper will contribute towards policy, training and research with regards to the bottlenecks impeding technological innovation among women farmers in Ghana.

Résumé

Pendant de nombreuses décennies, les femmes ont été considérées dans le cadre des politiques agricoles au Ghana comme des " agricultrices à temps partiel " plutôt que des agricultrices de plein droit. Elles ont généralement été présentées comme les épouses des paysans ayant pour principale tâche de fournir de la main-d'oeuvre familiale. Bien entendu, cette conception a considérablement changé au cours de la dernière décennie et a été remplacée par une image plus réaliste faisant des femmes des agricultrices. A présent il est largement reconnu que les femmes produisent selon les régions 25 à 50 pour cent ou plus des cultures vivrières au Ghana. Dans nombre de pays africains, cette situation a entraîné l'adoption d'instruments politiques visant à conférer des pouvoirs aux agricultrices. Cependant, la matérialisation de ces instruments ne s'est pas encore faite, et par conséquent les technologies qui révêtent une grande importance pour les paysannes restent largement en dehors du circuit de la recherche agricole et du développement. Cette communication aborde les circuits non-formels du transfert et de l'expérimentation des technologies semencières chez les productrices de cultures vivrières dans certaines régions du Sud-Est du Ghana. Elle examine par ailleurs les conditions dans lesquelles les femmes adoptent de nouvelles technologies semencières ainsi que les différentes implications pour la politique agricole au Ghana. Les contraintes qui empêchent directement les femmes d'adopter les semences de variétés améliorées ont également retenu l'attention. Les données utilisées proviennent d'une étude menée dans les districts de Dangme Est et Dangme Ouest ainsi que dans le district de Tongu Nord. Des entretiens de groupes-cibles et des entretiens individuels ont été réalisés avec un nombre total d'environ 100 femmes et un nombre d'hommes équivalent. Il est à espérer que cette communication sera une contribution à la politique, à la formation et à la recherche en ce qui concerne les goulots d'étranglement entravant l'innovation technologique chez les paysannes au Ghana.

Introduction

Improved low-input seed technology has attracted international attention, as a critical component in any process for achieving sustainable production among small-scale farmers. A shift to relatively low-input seeds would, however, call for fundamental changes in existing seed production research frameworks, away from high production costs, and the heavy dependence on chemicals and other forms of modern technology (Fernandez, 1994; Sperling *et al.*, 1993). The new framework for seed production in a sustainable process would be expected to focus directly on local systems of seed technology and how best to improve them. Research into local seed distribution channels is expected to give researchers the benefit of local knowledge and practices as a first step towards redesigning formal seed transfer strategies.

Women have recently been widely acknowledged as essential for attaining success in any research venture on seeds, because of their important role in seed preservation and agricultural technology transfer. At the same time, it is recognized that existing traditional institutions often exert pressures on women in addition to limiting their access to technology, including seed technology. It is in this context that studies were conducted into gender issues in the seed sector, from which the information for this paper has been extracted. The research was undertaken in the Ga-Dangme and, to a limited extent, Tongu coastal savannah food production zone in south-east Ghana. Overall, about 60 women and 60 men were interviewed individually; in addition, focus group discussions were held with about 15 groups of men and women farmers at separate fora. The study took place between 1991 and 1993.

In the past the conventional perspective on women as "farmers' wives" led to their relegation to home management extension programmes. But this has long since been replaced with a more clear understanding of women as farmers in their own right, each having major responsibility for domestic food provisioning. In many areas in Ghana, as elsewhere in sub-Saharan Africa, women's contribution to food production compares favourably with that of men. All over the region, there are indications that in spite of their essential role in food production, women remain outside the mainstream extension programmes. Thus, reforms in the delivery of extension services are yet to reach the small-scale women food producers. The consequences of this state of affairs on food production, in general, and on the ability of women to sustain domestic food provisioning in resource-poor communities, in particular, has received considerable attention in the past decade.

The broad purpose of this paper is to provide a better understanding of the local dynamics of seed mobilization among men and women farmers in Ghana, with a view to finding appropriate ways of seed technology dissemination. The paper focuses specifically on analysis of local seed transfer systems, and on the ways in which men and women influence this process in their communities in the Ada area. In addition, attention is given to the differential impact of existing local seed transfer systems on men and women farmers. Seed transfer in this paper refers to the distribution of seeds of both old and new crop varieties.

Seed saving in general is an age-old practice among traditional small-scale farmers; consequently, most of them depend on their own seeds. While they concentrate on preserving seeds of the best adapted varieties in their environment, farmers are continually augmenting this supply with seeds of new and improved varieties. Opportunities for the introduction of seeds of new varieties arise when there is pressure or crisis in ecological patterns to an extent that food security is threatened, and seeds of old varieties are lost or drastically reduced. Such disasters may compel hard pressed farmers to consume their planting seed. In ordinary times, however, improved seeds may still be introduced into the community if they are those of varieties demonstrated to be of superior quality. The sections that follow examine the patterns of seed transfer for both old and new varieties, by focussing on: (i) distribution channels, and (ii) attitudes to experimentation as a basis for seed transfer.

Seed Distribution Channels

Friends, relatives and seed 'gifts'.

Channels through which seeds are distributed to the farming community have remained informal over the decades. From friends and neighbours, farmers not only learn about new varieties, but also acquire seeds of both old and new varieties. A young farmer about to establish his or her own farm may obtain her first planting seed from a female relation or a neighbour. Where the beginner farmer had previously assisted the donor with labour, the seed is often given free of charge in appreciation of that labour if the latter had not already been paid in cash or in kind. More important sources of seed for new farmers are maternal and paternal relations.

Maternal relations have been shown to be more generous in providing seed as gift to the beginner, while paternal relations often provide such seeds at some cost to the new farmers. Typically such transfers are accompanied by instructions on the handling of the seed and its subsequent use in crop production. Even when seed is provided as a gift, the beneficiary is expected to reward his benefactor after harvest. For example, a 'gift' of one 'olonka' (5 kg) container of planting seed, may attract two 'olonka' containers in return as a token of appreciation. In some cases this mode of exchange is recognized as an economic transaction described as 'seed borrowing'. Table 1 summarizes the methods by which both men and women exchange seeds in the study area.

Table 1. Methods of seed exchange by gender in the Dangme/Tongu area of Ghana.

Method of seed exchange	Percentage of farmers	
	Women farmers	Men farmers
Seed gifts	70	9
Seed lending	49	24
Seed cash sale	38	40

Source: Field work in Ada, 1992. Multiple Choice.

The table shows that most women and men participate in multiple forms of seed exchange, though quite a large number claimed that they had never sold their seed for cash. In general, women are more involved in seed lending and borrowing than are men. To some extent, the mode of seed transfer in which a farmer participates is influenced by the nature of relationship between the parties involved in the exchange, as is demonstrated in Table 2.

Table 2. Mode of acquisition of first planting seed among farmers in the Dangme/Tongu area of Ghana.

Source of seed	Percentage of responding farmers			
	Women		Men	
	Gift	Purchase	Gift	Purchase
Maternal relations	26	-	8	3
Paternal relations	26	3	73	3
Spouse	10	2	-	-
Friends	7	-	5	2
Market traders	-	25	-	13
Extension officer	2	2	2	2
Others (farmers, FASCOM)	10	3	-	3

Source: Field work in Ada, 1992, multiple answers.

Table 2 shows that relations are not the only sources of seeds. Participation in seed exchange is also a function of financial capacity. The table suggests that the proportion of women that purchase their first planting seeds is higher than that of men, though women have a more evenly spread network of initial seed supply sources, compared to men. Several deductions can be made from this observation. For example, it suggests that men are able to satisfy more of their basic demand for seeds through reciprocal exchange networks compared to women. When the fact that most transfers within the family are along same sex lines is taken into consideration, it becomes clear that seed resources along female lines are more limited than resources along male lines in the family. This is supported by the fact that women traditionally receive more seed 'gift' from their spouses than they are able to extend.

Contrary to expectation, no difference was found between the reliance of men and women on the extension officer for first seed supply. Perhaps this can be explained by the fact that new farmers look to the family for material and moral support to get started; it also indicates that informal channels remain the most accessible sources of supply of seed, compared to formal seed distribution services. After they have acquired their first planting seeds, most farmers normally proceed to save their own seeds from the harvest rather than go back to the initial supplier. However, it is quite usual to augment one's seed through regular seed purchases from the market or from other farmers. It is important to note that some farmers are said to 'specialize' in seed production.

Though intra-community seed diffusion appears to work, and indeed has sustained small-scale farmers, it has important limitations that are often overlooked in ethno-agronomic studies. In practice, farmers are reluctant to distribute seeds to others outside their networks of exchange. This implies two things: first, distribution is more or less restricted to family members and close friends or colleague farmers; second, poorer farmers who may suffer periodic or chronic food deficit situations would automatically not be in a situation to participate in seed exchange networks (Sperling and Loevinsohn, 1992). What is the gender significance of such an observation? In the Dangme/Tongu areas it was established that women on the average had smaller acreage under cultivation than men and were more likely to experience labour shortages. In addition, their use of agro-chemicals was usually lower compared to men. As a result, women were more predisposed to experience lower yields and seed deficits compared to men. This undermines their ability to participate effectively in seed exchange, and compels them to purchase seeds more often than men (Table 2). For those who are obliged to purchase seeds, the markets are said to be a reliable source of supply with a wide range of varieties.

Markets and traders in seed transfer

Historically in the Dangme/Tongu area, new food crop seeds enter the communities through traders. During visits to various markets in the study areas it was revealed that foodstuff traders, most of whom are women, routinely bring samples of what they consider to be attractive varieties from various parts of the country to show to their friends and customers. In this manner, the traders have been among the first line of contact and information about new seeds for many women as well as men. The introduction of a hitherto unknown Bambara groundnut variety into the Ada area by traders illustrates this point.

About thirty years ago, women traders brought a reportedly prolific, drought resistant and larger Bambara groundnut from northern Ghana known as the "Jabajaba" to the Ada area. This was at a time when the local Adaa variety was not doing well due to a severe drought and disease attack; the farmers were therefore quite ready to try a variety that was reputed to survive drier conditions. Today the Jabajaba is widely cultivated in the area, alongside the old Adaa, which was not discarded due to its preferred texture and taste. Though women traders have a longstanding reputation for introducing new seeds, the actual spread of the seeds does not preclude the involvement of men. At Matsekope, in the Ada area, it is Tseko Odoba who is credited with the introduction of the Jabajaba variety into the village. The old variety Adaa was also said to have been introduced in the 19th century by a male trader and farmer called Bisensu.

Sometimes the supply of seeds from women traders to farmers becomes an integral aspect of the trade transaction. The traders may actually influence the adoption of a new variety by farmers through other concrete steps that go beyond the introduction of the seed. They have in the past, for example, provided credit to finance input supply for farmers to assist them with the adoption of a new variety. Tomato and okra farmers in the study areas are regularly given seeds of popular or improved tomato varieties by the wholesalers who come to buy their produce. This relationship normally continued until the farmers manage to establish a stock of seeds of their own after a few seasons. In comparison, formal channels of seed distribution have had a relatively limited impact on satisfying farmers' seed needs.

Non-formal channels of seed distribution, despite their popularity, are not trouble-free. There are no systematic quality controls, even where goodwill dictates that the seeds transferred should be of the best available quality. Thus, there is room for formal seed supply institutions to disseminate information on quality control among farmers and traders.

Formal seed distribution services

There is general agreement that the formal institutions play only a small part in the distribution of seeds, though their involvement has gathered momentum in recent years. The formal seed distribution sector is said to supply less than 10 percent of farmers' seed requirements in Ghana. The low involvement of formal seed supply agencies in the transfer of new seed technologies in most parts of Ghana is best illustrated with the experience of farmers in the Dangme/Tongu area. Only 25 per cent of the women in the study obtained new seeds (mostly of maize and cowpea) at one time or the other from an extension agent, compared to 68 per cent of the men. In the majority of cases, these were restricted to maize and cowpea seeds. Apart from the extension department, seed companies have also provided seed to a few women farmers. Men and women may look for quite different qualities in improved seed, popularly known as "agric seeds". Though higher yield was said to be the most significant attraction among the men, it was rather earliness that women identified as the major advantage of "agric seeds". The albeit cautious reception of "agric seeds" in the Dangme/Tongu area is an important indication of the willingness of the people to experiment with unfamiliar planting materials. There have been other problems with improved seeds. Prominent among these is the farmers' complaint that these seeds have very low viability.

Gender and Experimentation with New Cultivars in the Dangme/Tongu Area

By all indications, an impressive number of women farmers in the Ada area, like their male counterparts, have a strong inclination to experiment with new seeds. This is demonstrated by the fairly large proportion of men and women who regularly or sometimes try new seeds. Table 3 summarizes general attitudes to new cultivars among men and women in the study area.

Table 3. Percentage of farmers who try new seeds in the Dangme/Tongu areas of Ghana.

Previous involvement with trying new seeds	Men farmers	Women farmers
Tried them as often as available	67	41
Tried them only, occasionally	24	47
Never tried them	9	12

Source: Field work in the Ada area, 1992.

It appears that a larger proportion of men are willing to take risks with new seeds compared to their women counterparts. Women, because of their greater dependence on seed purchases, are perhaps more anxious to ensure that they achieve good results, and therefore seek greater verification and assurance from their networks before they take the major step to commit resources to a new variety. It is worth mentioning at this point that the adoption of new seeds will normally not be allowed to undermine the survival of old varieties. Irrespective of their attitude to new seeds, most farmers continue to grow old varieties. Maintaining traditional seed stocks is regarded as a necessity for ensuring food security in the community.

A major question that needs to be addressed in connection with the propensity to experiment among farmers is: what are the contributory factors that predispose men and women farmers to experimentation? Demonstration of superior qualities of the new seed and local acceptance appear to be key factors, particularly for women. Many wait for their neighbours to try it first, or to recommend it to them. Others are motivated by seeing attractive new varieties with neighbours or at the market. Table 4 summaries the factors that influence experimentation with new seeds by farmers.

Table 4. Gender and factors that influence experimentation with new seeds (in per cent) in the Dangme/Tongu areas of Ghana.

Factor	Percentage of responding farmers	
	Men	Women
Promising results of own trial	44	41
Neighbours recommendation	26	46
Extension officers' recommendation	30	13

Source: Field work in the Ada, A992.

The data presented in Table 4 indicate that those women that are in a position to take advantage of innovations are as experiment-oriented as their men counterparts. However, more men were convinced to try new varieties, compared to women, while more of the latter were encouraged to try new varieties by their neighbours compared to their men counterparts.

It was also considered important to find out why about 10 per cent of the farmers (Table 3) have never tried new cultivars. About 48 per cent of the farmers who had never tried new varieties identified mistrust of new varieties as their major reason. Among women farmers, lack of information was also a major factor. Other factors included lack of funds which affected more women than men. In addition, 25% and 17% of the women and men, respectively, identified the higher costs of new improved seeds as their main handicap.

Conclusions

Among small-scale, low-input producers of the Dangme/Tongu area, the most widely used systems of seed technology dissemination are informal channels, including local seed 'gift' exchange networks. Usually seed exchange is practised amongst relations, neighbours and other farmer friends. The local markets are also important sources of supply, as are local farmers who have specialized in seed production.

Participation in seed 'gift' exchange networks, is to some extent motivated by the potential returns as the receiver is obliged to reciprocate this kind gesture in seeds, sooner or later. Where the exchange is guided by clearly laid down norms of reciprocity, as in seed lending, the costs of receiving such 'gifts' can be quite high. For this reason, partners in the exchange are carefully selected, indicating that it is not automatic for all small-scale producers to benefit. In the Dangme/Tongu area, women have several channels of seed transfer, but this conceals the fact that they are able to mobilize less of their needs from 'gift' transfers compared to men. In general, men appear to receive greater seed supply from other men in the family.

To supplement seed obtained through networks many men and women purchase seeds to meet their total needs. However, compared to their male counterparts, women tend to rely more heavily on seed purchases.

Old varieties are heavily protected from extinction, but the need to augment their supplies of seed is highly appreciated by both men and women farmers. A considerable amount of experimentation with new seeds occurs among both men and women, though women have shown greater risk aversion compared to men.

The findings of the study point to the need to promote local knowledge based research into channels of seed transfer, as a basis for improving these channels at affordable costs. The study further highlights the active role of women in the process of seed transfer; it also shows their relative disadvantage in enjoying the full benefits of the local networks. Weaknesses in the system of non-formal seed transfer include inadequate attention to seed quality, but this is primarily attributed to lack of information.

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Rural Women and Agricultural Extension Delivery in Nigeria

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Abstract

It is an indisputable fact that women's contribution to agricultural production have neither been appreciated nor given due recognition. This had happened inspite of the fact that women put in more hours than men on the agricultural production.
The official priotity given to men is rooted in societal expectations which demand that women's position should always be one step behind the men's. As a result, official recognition of women's role in agricultural production continues to remain in the periphery at the planning, policy and legislative levels.
Much of this paper is based upon views accumulated on gender related agricultural extension issues. These views permit relevant recommendations to be made on the issues of women agricultural extension delivery.

Résumé

Il est un fait indiscutable que la contribution des femmes à la production agricole n'a été ni appréciée ni dûment reconnue, et ceci bien que les femmes consacrent plus d'heures de travail dans l'exploitation agricole que les hommes en raison de la plus large gamme de tâches qu'elles accomplissent dans l'ensemble.

La priorité officiellement accordée aux hommes vient du fait que la société exige que la place des femmes soit toujours un pas derrière les hommes. De ce fait, le rôle officiellement reconnu aux femmes dans la production agricole continue d'être périphérique tant au niveau de la planification qu'à celui de la politique et de la législation.

Cette communication se base essentiellement sur des considérations relatives aux questions féminines dans le domaine de la vulgarisation agricole. Ces considérations permettent de formuler des recommandations pertinentes en matière de vulgarisation agricole auprès des femmes.

Introduction

One important issue that has featured recurrently in the agenda of policy makers, politicians, gender analysts, and theorists recently in Nigeria is how to incorporate women as integral part of agricultural development. This derives from the fact that women provide some 60-80 percent of the agricultural labour force (Ngur, 1987; Akor, 1990; Blumber and Okoro, 1991) and their input into agriculturally related decision-making is believed to be substantial (Saito and Weidemann, 1990). Figures are not available on the contribution of women to various agricultural operations; however, observations show that in addition to their nurturing and reproductive roles, women are responsible for much of the hoeing, sowing, weeding, bird-scaring, harvesting, and almost all processing, transportation, storage and marketing of crop and animal products.

In pastoral communities, where boys are absent or fewer than girls, the women and girls take a large responsibility for cattle rearing, and in places where stall feeding is practised, women generally have the responsibility for this job. Muslim women in purdah process food for sale within the confines of their homes and when men move into new income-generating activities, such as cash cropping and white collar jobs, women may have to assume the whole burden of food production, in addition to their household and family responsibilities.

Despite these multiple roles, rural women in Nigeria had, until recently, been perceived as basically peripheral to agricultural development programmes. Consequently, they have generally been ignored. The purpose of this paper is to high-light the role of rural women and the recent trend in agricultural extension delivery in Nigeria.

Nigerian Agricultural Extension System

To really understand rural women and extension delivery in Nigeria today, one must have an understanding of the history of the Nigerian extension system. Some people claim that since the colonial era (1880-1960), the most basic and relevant approach taken to improve agricultural production and well-being of small-scale farmers has been agricultural extension. Within this approach, a variety of strategies have been tried with varying degrees of success.

During the colonial era, effort was made at laying down basic institutions that support agricultural development and gathering of scientific information through experimentation. Prominent among these was an elementary extension service which started in 1921. At later dates, schools of agriculture, forestry schools, and a veterinary training school were established for the training of junior technical officers. The promotion and distribution of new crop seedlings or seeds, such as oil-palm, cocoa, rubber, cotton and groundnut dominated the extension activities of the time. Adequate extension activities geared towards production of food crops (traditionally women's crops) were neglected. At the same time, personnel recruitment and agricultural training favoured the male sex. The assumption was that agricultural messages given to men would trickle-down to their wives, a situation which hardly occurred. General neglect of both women's crops and women's training meant that the majority of the farmers were neglected. It is generally agreed that these initial approaches and attitude have directly or indirectly influenced extension delivery in the post-independence period (Eicher and Baker, 1982; Hart, 1982; Wallace, 1983).

The then Western, Eastern and Mid-Western regional ministries of agriculture in the 1950s and early 1960s, embarked on farm settlement schemes which were meant to attract the youths to farming career and to serve as demonstration plots to other farmers. These farm settlements did not succeed, principally because of mismanagement and the non-involvement of female farmers who constituted the bulk of the food producers.

The era in which the regional ministeries of agriculture provided most of the extension services was followed in the 1970s by a second era during which several extension programmes were established; these included the National Accelerated Food Production Programme (1973), the River Basin Development Authorities (1975), the Operation Feed the Nation (1976), and the Green Revolution Programme (1979).

Some of these programmes have had to be abandoned at some point in time due mainly to their perceived ineffectiveness. But one of their major flaws was that virtually all of them were planned and implemented with little or no regard to the important role of women as food producers (Olayiwole, 1987).

The World Bank-assisted Agricultural Development Projects (ADPs) model is currently being tried. The ADPs, which started in the mid-70s, are joint ventures involving the World Bank, the Federal Government and the State Governments. The ADPs focus on the small-scale farmer who is the centre-piece of all agricultural development efforts in most developing countries. The projects now have responsibilities for extension delivery, covering all the agricultural sub-sectors, in the entire country.

Besides the general government extension services, there are a few private extension programmes such as those of the Nigeria Tobacco Company, Vegetables and Fruits Processing Company, Africa Cotton Company, and Nigeria Sugar Company, all of which are commercial companies; there are also a few non-profit making extension activities of Christian organizations. However, the tendency to concentrate on cash crops and to favour male farmers has continued to dominate the extension services of these private agencies (Mohammed, 1987; Omotayo and Akpoko, 1995).

Special Extension Approaches to Assist Rural Women

Development of home economics strategy to assist rural women

In general, the task of extension work is to help rural families apply science to the day-by-day routine of farming, home making and other aspects of rural living. The first noticeable extension strategy to assist rural women was the provision of home economics education (Aidoo, 1988).

Prior to 1976, when a Home Economics Section was established in the Crop Production and Protection Division of the Federal Department of Agriculture, there was little coordination of the activities of individual home economists who were scattered in various institutions. By the early 1980s, the Home Economics Section became a Division with responsibility for the development of programmes to promote and enhance the well-being of women and children, particularly in the rural areas. By 1984, there were 6,000 Home Economists in the country (UNDP/ILO, 1986).

The better life programme (BLP) for rural women

The need to improve the well-being of women gave birth to the "Better Life Programme (BLP) for Rural Women" in 1986. The activities of this programme included the supply of farming inputs, disbursement of loans, encouragement of women to form cooperative societies and the provision of home economics education. The programme was organized from the grass root level.

Despite criticisms levelled against the BLP, it had, indeed, made a dent in women's thinking both in the rural and urban areas. A Central Bank of Nigeria Report (1991) supports the view that the BLP has contributed in enabling rural women to have equal access to production inputs with the men.

The women in agriculture (WIA) programme of the ADPs

In Nigeria, problems of women are high-lighted by a network of women societies under the umbrellas of National Council of Women Society (NCWS), National Commission for Women, the Women in Agriculture (WIA) programme and, more recently, the Federal Ministry of Women Affairs and Social Welfare (MWA & SW).

Prior to the WIA programme, the extension agents and most of their contact farmers were males. The World Bank, the principal financier of the ADPs, having recognized the role of women in agriculture, recommended the establishment of a special Women in Agriculture (WIA) unit within the Agricultural Development Projects.

The WIA programme started as a pilot programme in the Imo State ADP in 1986. In 1987, similar programmes were initiated in Ogun, Cross River, Gongola, Kano and Niger States. The pilot programmes started by hiring a few female extension agents who had previous training in agriculture. They worked with both male and female farmers. The experiment was successful and more females were employed for extension activities.

Since 1988, the popularity of the WIA programme has spread and it is now replicated in all the ADPs. The programme aims at increasing the productivity and income of women. The specific objectives of the programme include:

i) to identify the constraints faced by women farmers;
ii) to source suitable technologies to alleviate identified constraints;
iii) to ensure timely extension support to women farmers in the area of agricultural production, processing, and utilization;
iv) to provide advice to women on the formation of groups so that they can gain access to farm inputs and credit; and
v) to introduce labour saving technologies in the activities of women farmers.

At the Headquarters, WIA Programme is headed by a Deputy Director with overall responsibility for the planning and implementation of the programme. At the zonal level, there are subject matter specialists (SMSs) for WIA who supervise and monitor the implementation of the zonal programmes. Similarly, at the block level, there are WIA block extension agents (BEAs) who work mostly with women farmers; they spend about 70 percent of their time on agricultural production related matters and 30 percent on post harvest technology related problems. BEAs (WIA) have specific responsibilities to identify and organise women into groups and to liaise with cooperative society inspectors to register women groups into cooperative societies.

At the circle or village level, there are no separate extension agents (EAs) for WIA. However, an understanding has been reached that at least 30 percent of all EAs in an ADP should be females who should ensure that at least 60 percent of their contact farmers are women. Furthermore, all EAs (men and women) are to disseminate information to all farmers where no religious/customary barriers prevent such contacts. Operationally, the Training and Visit Extension System in use in the ADPs provides the basic strategies for extension support to the WIA programme.

In the last three years, the WIA programme has placed emphasis on four activity areas:

. ensuring that the organisational structure for providing needed extension services to women is in place;
. getting block and village level extension workers to establish necessary contacts and rapport with women farmers;
. sourcing and demonstration of improved technologies which attempt to solve the identified constraints faced by women farmers; and
. establishing appropriate linkages between WIA Programme of the ADPs and other women programmes being undertaken by other agencies.

In the above areas, some modest achievements have been recorded.

Constraints to Effective Implementation of the WIA Programme

A broad outline of some of the constraints to effective implementation of the WIA programme in Nigeria is presented here in order to provide the basis for discussing priority areas to improve the performance of the programme.

The efforts of the ADPs to implement the programme is being constrained by inadequacy of experienced and skilled female personnel. At present, the majority of the female extension staff in the WIA units are Home Economists. The benefits of the WIA can only be realised if the proper cadre of extension personnel and adequate number of field staff are recruited and trained for the implementation of the programme in all the ADPs.

Extension agents cannot visit farmers without reliable transportation. Many of the villages are far from the main roads, making public transportation unreliable. Consequently, only villages located near main roads benefit from extension visits. Provision of bicycles and motorcycles greatly enhances the performance of extension workers. Indeed, Safo *et al.* (1990) consider access to transportation as the most basic requirement for effective extension work. The ADPs are addressing the problem by providing staff loans for procurement of motorcycles. However, it is important that the needs of female staff receive adequate attention.

Recent experiences in Nigeria have shown that critical issues such as staff discipline, training and promotion are often adversely affected by political interference. For the

WIA programme to succeed, it must be strictly insulated against political manoeuvres and opportunists.

Funding is a critical factor in the implementation of any programme. The ADPs are not exempted but detailed discussion of the problems is beyond the scope of this paper. However, effective implementation of the WIA Programme under the ADPs calls for greater funding commitments by both the Federal and the State Governments.

Perhaps closely linked with the issue of States and the Federal Government funding, is the issue of the World Bank financial support. There are serious doubts about the ability of Nigerian government to maintain the present level of funding for the ADPs when the present World Bank funding ceases. The sustainability of any externally supported development project depends largely on the level of commitment of the implementing agencies and the government. With the present unimpressive funding commitment by both the States and the Federal Government, the fears about sustainability of funding with the cessation of World Bank support are real.

Suggestions for Better Implementation of the WIA Programme

There are indications that the country is now developing a progressive rural women agricultural extension delivery system that can endure the test of time. However, much still has to be done to sustain it. The following are suggestions for further improvement of the WIA programme.

(i) The emphasis of the WIA programme is currently on group formation, rice, maize and root crops production. Effort should be made to integrate millet, sorghum, wheat and cowpea extension activities into the WIA programme, since these are some of the food staples for a majority of the people.

(ii) Pre-service training schemes of female extension staff in the WIA programme are relatively under-developed. In this respect, the curricula of training institutions should be reviewed in line with recent development and actual rural women's problems.

(iii) It is generally acknowledged that credit to farmers is one of the most important instruments in accelerating the adoption of new technologies. This applies especially to rural women, whose low capacity to save money and lack of sure avenue to acquire credit seem to be crucial factors limiting farm development. To ameliorate this situation, government should provide sure and secure avenues for acquisition of credit facilities necessary to practise modern agriculture.

(iv) Women's tasks are varied, time and energy demanding; therefore, women require inputs that can save them time and drudgery. In Nigeria, however, many of the labour saving devices extended to women have not been adapted to the special needs of women. Government and researchers should give urgent attention to this problem.

(v) The issue of funding the ADPs has been high-lighted above. For emphasis, it is strongly suggested that the proposal to establish a National Agricultural Development Trust Fund should be favourably considered without further delay.

(vi) One of the visible problems with private extension agencies is their gender bias. Government should put in place a policy which ensures that women are accorded fair consideration by these NGOs.

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CHAPTER IV

Sustainable Agriculture

Technological Options for Sustainable Agricultural Production Systems in the West African Semi-Arid Tropics

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Abstract

It has been estimated that by the year 2025, there will be nearly one billion additional people to feed, shelter, provide energy and jobs in sub-Saharan Africa (SSA). The physical and economic obstacles to the use high-input responsive technologies (i.e., fertilizer, pesticides, etc.) in SSA and the recent concern for environmental safety, have created more interest and impetus for the development of low-input based sustainable agricultural production systems, which could maximize the utilization of on-farm available resources. The dilemma of African agriculture is, thus, to meet the challenge of food production for the increasing population, without depleting the natural resource base.

Throughout the discussion of this paper, sustainable agricultural production systems is perceived as a viable dynamic concept, that integrates sub-components of farming practices to: i) enhance recycling of renewable on-farm resources, ii) induce economic complementarity between sub-systems of production, and iii) promote conservation of natural resources.

Based largely on Farming Systems Research (FSR) work carried out in Burkina Faso and, to a limited extent, in the northern parts of Benin, Cameroon and Ghana, the paper examines the appropriateness of available technological options for the development of low-input sustainable agricultural production systems in the West African Semi-Arid Tropics (WASAT).

Résumé

Selon les estimations, il y aura vers l'an 2025 près d'un milliard de personnes en plus auxquelles il faudra assurer la nourriture, le logement, l'énergie et l'emploi en Afrique Sub-Saharienne (ASS). En ASS, les obstacles physiques et économiques à l'emploi de technologies répondant à un niveau élevé d'intrants (i.e. engrais, pesticides, etc.) et la récente préoccupation pour la sauvegarde de l'environnement ont suscité un plus grand intérêt et un effort pour le développement de systèmes de production agricole durables utilisant peu d'intrants et susceptibles de maximiser l'utilisation des ressources disponibles en milieu paysan. Le dilemne de l'agriculture africaine consiste donc à relever le défi de la production vivrière pour la population croissante sans épuiser la base de ressources.

A travers cette communication les systèmes de production agricole durable à faibles intrants sont perçus comme un concept dynamique viable qui intègre les composantes des pratiques agricoles pour i) promouvoir le recyclage des ressources renouvelables en milieu paysan, ii) instaurer la complémentarité économique entre les sous-systèmes de production et iii) promouvoir la conservation des ressources naturelles.

Principalement basée sur les travaux RSP menés au Burkina Faso et dans une moindre mesure au Benin, au Cameroun et dans la partie Nord du Ghana, la communication examine l'opportunité des options technologiques disponibles pour la mise au point de systèmes de production agricole durables à faibles intrants dans les Zones Tropicales Semi-Arides d'Afrique de l'Ouest.

Introduction

The features of traditional farming systems include low costs of inputs, energy efficiency, and integrated production systems which reduce risks to small farmers. In the three major savanna ecosystems (the Sahel, Sudan and Guinea savanna zones), cropping systems that are adapted to low and erratic rainfall and drought have evolved in the past several decades. Traditional cropping systems may include shifting cultivation: two to four years of crop farming, alternated with a long fallow period (5-15 years). The native vegetation serves to regenerate the soil through nutrient cycling and litter. The period of cultivation and fallowing varies from country to country, based on availability of land and population pressures. In fact, the practice of shifting cultivation has gradually disappeared in West African Semi-Arid Tropics (WASAT), and has been replaced by farming systems of increasing intensity in response to population growth.

The exploitation of the natural resources of a specific agroecosystem without concurrent replenishments of the soil nutrients, the traditional practice of separate crop and animal husbandry (i.e., transhumant nomadic herding and settled crop growers), rapid population growth, etc. have resulted in increased pressure on the land and intensification of cultivation. Every year, not only are millions of hectares of new land brought under cultivation, but intensified use of land already under cultivation has resulted in the degradation of the natural resource base which supports productive and sustainable agriculture.

The green revolution technological packages, being chemically based, have led to an accelerated use of non-renewable resources. Maximum use of fertilizers and pesticides has contributed to air pollution, contamination of ground water, and to loss of biological diversity. Recent technology development initiatives have resulted in the modification of the "green revolution" into several forms of integrated agriculture; for example, integrated pest management (IPM), and integrated plant nutrient systems (IPNS). The climatic and economic conditions required for green revolution agriculture to make a significant impact in food production in Africa hardly exist, mostly because of erratic rainfall, poor soil fertility, high costs of external inputs, etc.

Low external input and sustainable agricultural production systems enhance biological and economic complementarity between sub-systems of production, namely crops, animals, trees, etc. It does not exclude, however, the use of relevant external inputs, but minimizes their level, by combining knowledge of traditional and modern agriculture, with principles and practice of organic farming and ecology to improve and sustain the productivity of specific agroecosystems.

Study Sites and Methods

On-farm resource management research was carried out largely in the Central Mossi Plateau, the most densely populated region of Burkina Faso. The rationale of the FSR activities in this zone has been that agricultural intensification would be more relevant in the regions of highest population density (40 to 60 inhabitants/km^2), since the traditional agricultural system can no longer meet the demands for food, shelter and energy for the growing population.

In designing the experiments, due consideration was given to resources that could be readily available to, and are within the economic reach of, resource-poor farmers. Most of the feed resource trials were, therefore, conducted on fallow land on selected village sites and some on abandoned land. Demonstration animal feeding trials were established on farmers' fields and on FSR village sites.

As indicated in Fig. 1, the study was carried out in three representative villages, namely: Yalka, in Sudano-Sahelian zone, with long-term average rainfall of 670 mm; Kamsoaghin, and Kamsi villages in the Sudanian zone, with long-term average rainfall of 800 and 820 mm, respectively. In general, the soil of the Mossi Plateau in Burkina Faso is characterized by low water retention capacity, poor soil structure, and low fertility (especially low levels of nitrogen and phosphorus). Mixed crop/livestock farming is the general practice with sedentary husbandry of small ruminants on farms, and cattle raising through collaboration with pastoralists. The average land holding per household in Yalka, Kamsi and Kamsoaghin was 4, 3 and 5 hectares, respectively (Prudencio *et al*,. 1986).

The research and development approach involved farmers themselves to demonstrate the resource and economic complementarities accruable through integration of crop/livestock/agroforestry enterprises. Concurrently, emphasis was placed on exploiting locally available resources. One- to two-hectare sites were used for the study. Except for improved varieties of cereals and forage legumes, farmers had made investments on small ruminants, forage and pasture lands. Experimental animals (sheep) for feeding trials were contributed by farmers. Farmers also managed the communal village sites, and their own farm included in the study (mostly through silage making and harvesting and storage of hay to sustain livestock during the critical dry period).

Agricultural resource management studies within the FSR framework in Burkina Faso included cropping systems, livestock and forage legumes, trees/crops integrated production systems, soil-water conservation and management practices, etc. Farmers themselves have managed these resources on various sites. Researchers and extension agents, not only monitored the implementation of the project, but also demonstrated the need for integrated agricultural resource management and development in order to sustain soil fertility and gain more income.

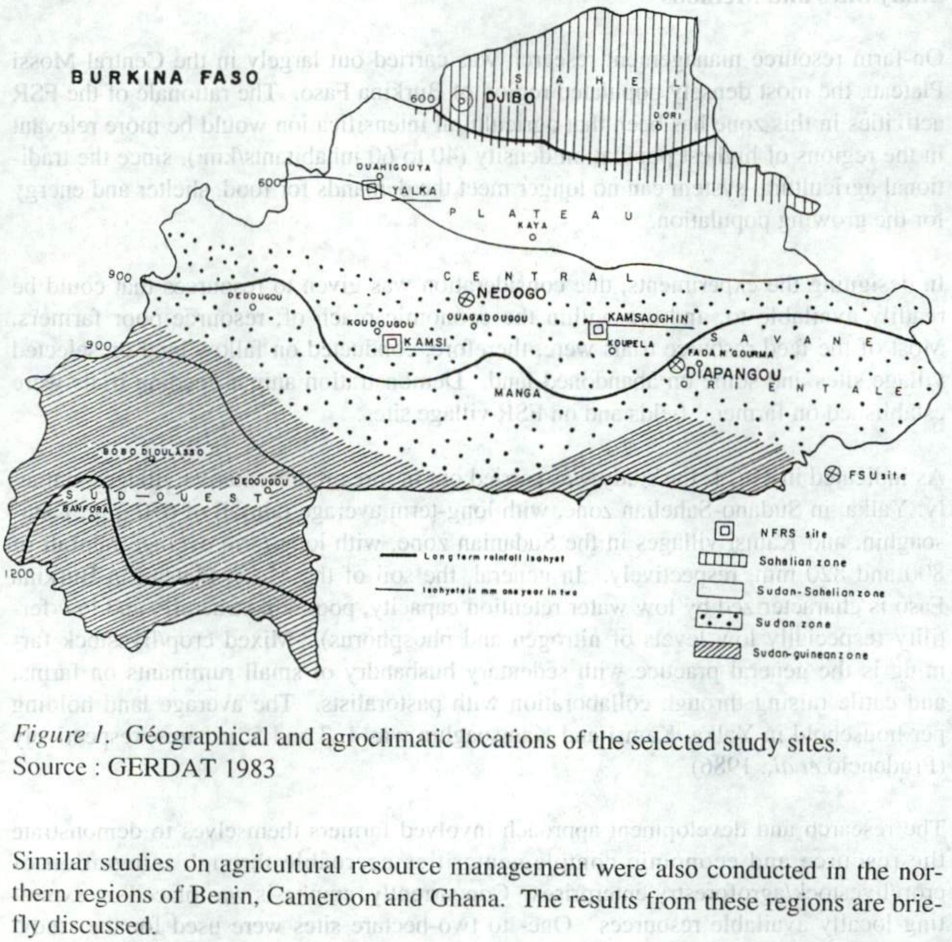


Figure 1. Géographical and agroclimatic locations of the selected study sites.
Source : GERDAT 1983

Similar studies on agricultural resource management were also conducted in the northern regions of Benin, Cameroon and Ghana. The results from these regions are briefly discussed.

Results and Discussion

In the WASAT, continuous cropping and the removal of crop residue is known to enhance depletion of essential soil nutrients, particularly nitrogen and phosphorus. The enhancement of soil organic matter, soil/water conservation and management, and crop-livestock integration are central to the development of low-input agricultural production systems.

Technological options for enhancing soil organic matter content

i) Cereal/legume rotation/association

The rationale of crop association includes risk aversion, maintenance of soil fertility, minimizing labour costs, and better insect and disease control. Intercropping of cereals/legumes also enhances biological nitrogen fixation and nutrient recycling in fallows. In Burkina Faso, the findings of Stoop and Van Stavern (1982) indicated that without fertilization, sorghum grown after cowpea yielded more than sorghum grown after millet.

Annual dual-purpose legumes were planted for the conservation of hay and for grain production. The amount of N fixation seems to vary considerably with the type of cereal/legume combination and systems of crop production (Singh *et al.*, 1986; Petra *et al.*, 1985 and 1986). The cowpea cultivar KN-1, *Lablab purpureus* and *Phaseolus aureus* planted on fallow land followed by cereals, produced total cereal biomass of about 5.2., 3.6. and 4.3. tons/ha, respectively. The contribution of nitrogen fixation (or nitrogen yield) from these crops was in the range of 158, 84 and 94 kg/ha, respectively (Yilala, 1988 and 1989). There are indications that cowpea cultivars selected for forage (being of long duration) tend to fix more nitrogen (Mulongoy, 1986 and Mulongoy *et al.*, 1988).

In the Upper West Region of Ghana, the effect of crop rotation on the yields of maize, sorghum and groundnut was investigated from 1990 to 1992 in a study involving 70 farm households in 14 villages. As summarized in Table 1, maize and groundnut yields in the rotation plots were significantly higher than those obtained using farmers' practice (Tetebo and Marfo, 1994). The average yield increases in rotation plots over those grown with farmers' practice were 36% for maize, 88% for groundnut and 30% for sorghum. Without rotation, maize yield declined from 2867 kg/ha in the first year to about 913 kg/ha in the third year, while groundnut yields decreased from 897 kg/ha in 1990 to 552 kg/ha in 1992; but sorghum yields only changed slightly during the same period.

In Benin, mixed cropping of leguminous trees with sorghum and cowpeas for soil fertility improvement, fodder and firewood has shown great promise. Grain yield increases of 47.0 and 44.3% were recorded for sorghum and cowpeas, respectively, in association with *Acacia albida* (Otsyina, 1989).

While the deficiency of soil nitrogen can partially be remedied through incorporation of legumes in the farming systems, the deficiency of soil phosphorus requires the application of fertilizer which also enhances the role of legumes in biological nitrogen fixation. The major part of phosphorus available to the plant usually arises from the microbial transformation of organic phosphorus. Composting might provide such benefits to the cereal crop and, applied at the rate of 10 tons/ha, gave equally high sorghum grain yield as that obtained by fertilization with NPK. The application of compost containing rock phosphate, feed remains and sheep faeces resulted in higher cowpea dry matter yield than that of plots fertilized with uncomposted rock phosphate or single superphosphate (Fig. 2).

ii) Crop residue

Several investigations in the past three decades confirmed that soil fertility in WASAT can be sustained through efficient use of crop residue, recycling of organic materials in combination with effective use of N-fixing leguminous species (in rotation), and fertilizer (Pieri, 1986). Particularly in the semi-arid zone, the proper use of crop residue can reduce erosion and runoff.

Table 1: The effect of crop rotation on grain yields of cereals and groundnut.

Crop	Yield (kg/ha) in rotation plots				Yield (kg/ha) in plots grown using farmers' practice			
	1990	1991	1992	Average	1990	1991	1992	Average
Maize	2758	3150	2250	2719	2867	2235	913	2005
Sorghum	863	923	1058	948	677	698	816	730
Groundnut	2071	1652	843	1555	897	1027	552	825

CV (%) : Sorghum 26, 25 and 20% for 1990/91/92, respectively.
Groundnut 28, 19 and 20% for 1990/91/92, respectively.
Source: (L.O. Tetebo and K.O. Marfo, 1994).

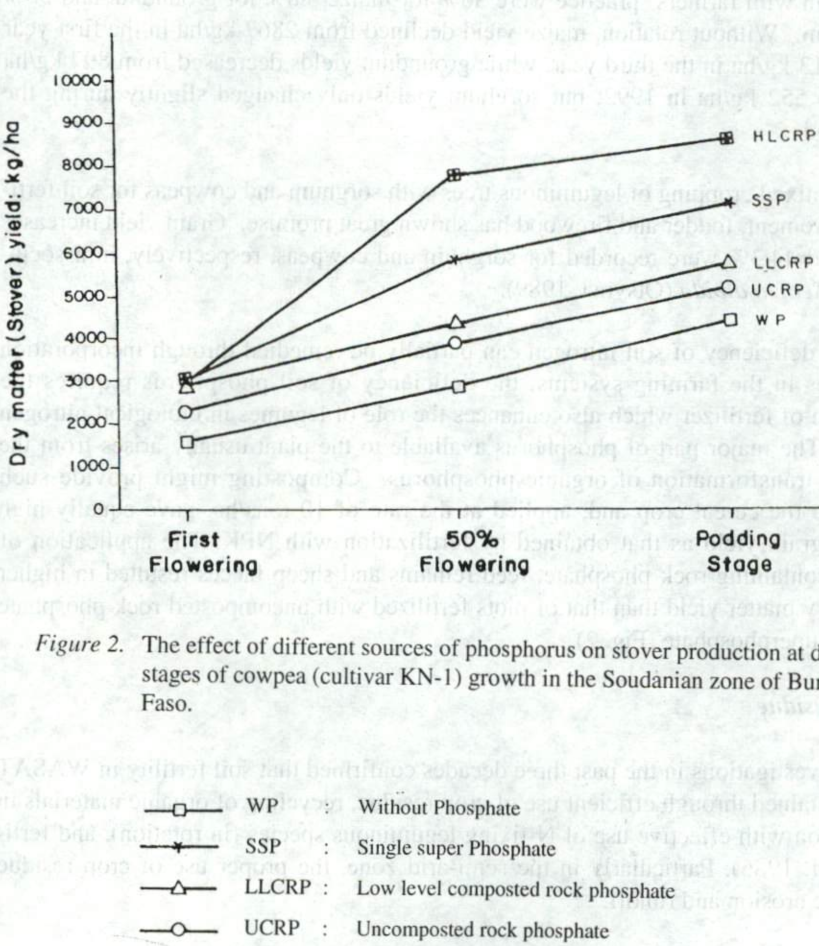
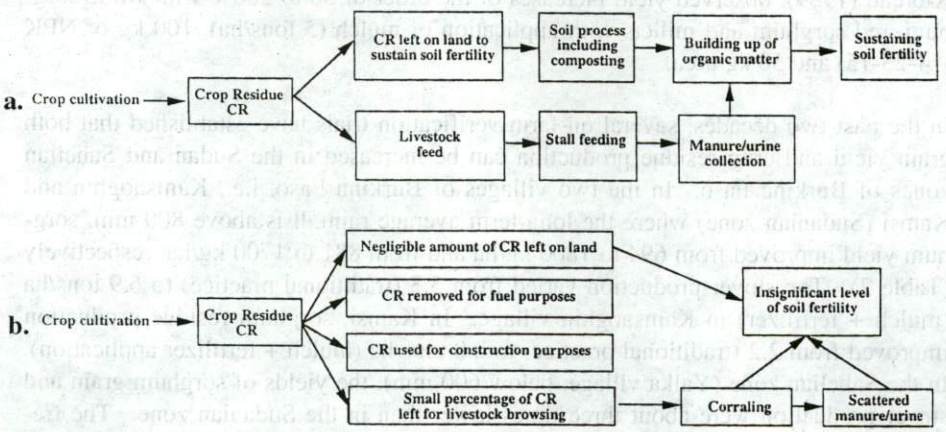


Figure 2. The effect of different sources of phosphorus on stover production at different stages of cowpea (cultivar KN-1) growth in the Soudanian zone of Burkina Faso.



a, Properly managed use of crop residue that enhances sustainance of soil fertility.
b, Actual traditional practice indicating competing uses of crop residue in WASAT (modified from Bationo *et al,* 1993).

Figure 3. Schematic outline for various uses of crop residue

Figure 3 gives two patterns of crop residue (CR) utilization. The traditional practice (Fig. 3-b) depicts different competing uses of crop residue. Following crop harvest, most residue is used as fuel, for construction of housing, and for animal feed. The alternative scenario (Fig. 3-a) depicts properly managed use of crop residue, where at least 70% of it could be incorporated into the soil and the remainder utilized as livestock feed. If livestock are penned for stall feeding, the manure (as returns from animals) and the crop residue can contribute towards sustenance of soil fertility. In the Sahel savanna, most of the crop residue (up to 50%) is grazed by cattle.

Based on studies done in Burkina Faso, Rodriguez (1988) showed a significant maize grain yield increase due to the application of maize residue in the Sudanian zone (Fig. 4). Under a high management system (tied ridges + fertilizer), maize grain yield increased to 3 ton/ha with application of about 5 tons/ha of crop residue. Yield of maize was generally higher with tied ridges than when grown on simple ridges under high and low managements. No significant difference in yield, however, was observed between management (fertilizer + tied ridges) levels, when crop residue was systematically removed (Rodriguez, 1988). The removal of crop residue has been detrimental to soil productivity and to the improvement of the physical structure of the soil (Hulugalle, 1989). Highest yields of millet grain and stover were obtained when crop residue is combined with fertilizer application (Bationo *et al.*, 1993).

Crop residue is in short supply in the northern half of WASAT. More crop residue to sustain soil fertility could be made available by planting trees in crop associations; the trees also provide materials for construction and fuel. Tied-ridging, mulch and moderate use of fertilizer not only have doubled grain yield of sorghum and millet, but also substantially increased the production of biomass (stover or residue). In this study, Kibreab (1989), observed yield increases of the order of 50 to 200% with white sorghum, red sorghum and millets with application of mulch (5 tons/ha), 100 kg of NPK (14-23-15) and 50 kg urea.

In the past two decades, several on-farm verification trials have established that both grain yield and crop residue production can be increased in the Sudan and Sahelian zones of Burkina Faso. In the two villages of Burkina Faso, i.e., Kamsaoghin and Kamsi (Sudanian zone) where the long-term average rainfall is above 800 mm, sorghum yield improved from 694 to 1800 kg/ha and from 881 to 1700 kg/ha, respectively (Table 2). The stover production varied from 3.3 (traditional practice) to 6.9 tons/ha (mulch + fertilizer) in Kamsaoghin village. In Kamsi, sorghum residue production improved from 2.2 (traditional practice) to 8.0 tons/ha (mulch + fertilizer application). In the Sahelian zone (Yalka village, below 600 mm), the yields of sorghum grain and stover production were about three times lower than in the Sudanian zone. The frequency and amount of rainfall, as well as management practices, have influenced grain yield and stover production.

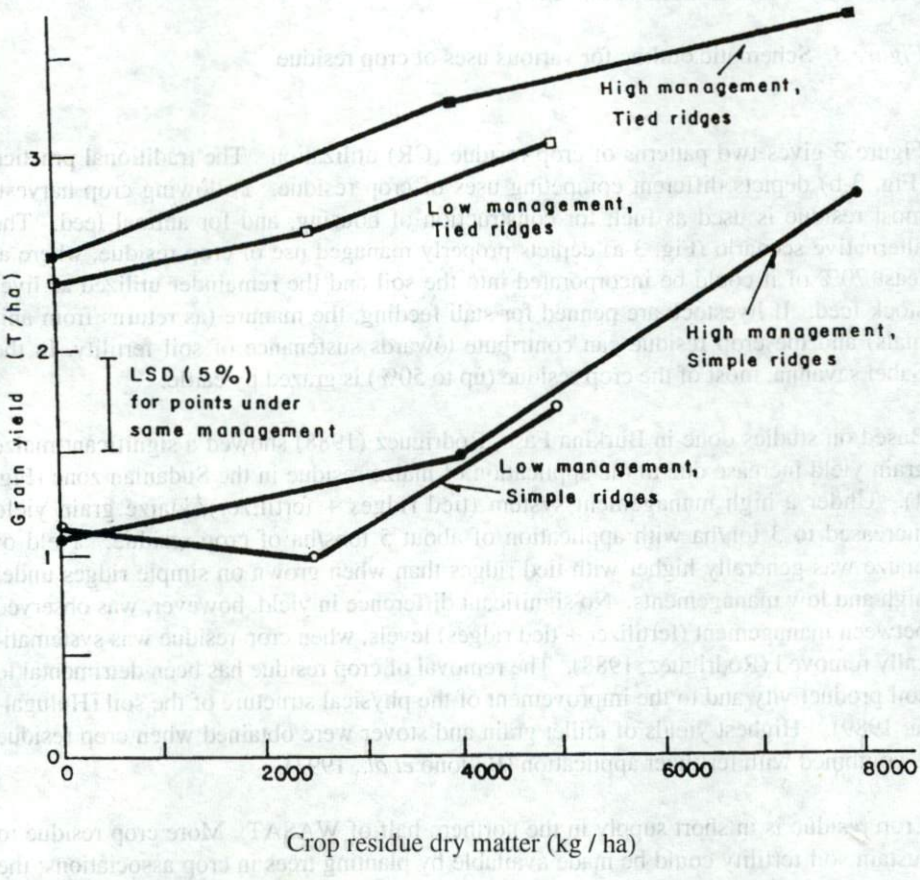


Figure 4. Effect of maize residues on maize yield under two ridging systems and two management levels (Rodriguez, 1988).

In the Sudanian zone (Kamsaoghin) of Burkina Faso (Table 2), millet grain yield and stover production increased from 796 to 1382 kg/ha and 5.8 to 7.6 tons/ha, respectively, with application of fertilizer and tied-ridging. The traditional practice gave 58% of millet grain yield and 76% of stover production compared to improved package of technology. In the Sahelian zone, however, millet grain and stover production were generally low, apparently due to recurrent droughts in 1987 and 1988.

iii) Animal manure

Manure is an important biological source available on-farm. In the Sudan and Sahel savannas, inadequate manure and organic residue supplies have been the principal constraints to sustainance of soil fertility. The traditional system of livestock raising based on nomadic pastoralism does not lend itself to maximum application of manure, unless cattle are penned to make its collection possible. This investigation was carried out in the Sudan and Sahelian zones of North Province of Cameroon. Ngambeki *et al.* (1992), after analysing data on integrating livestock into cropping systems in Northern Cameroon, suggested that stalling four cows could supply up to 5 ton/ha of manure every two years. In Northern Cameroon, the large livestock population makes it feasible to restore soil fertility by the application of manure. If properly managed, animal manure is an important means for maintaining soil fertility and increasing crop production. When manure is exposed on soil surface, 30 to 90% of nitrogen in the manure could be lost through ammonia volatilization (Vanderholm, 1975). Immediate incorporation into the soil or composting of manure could stabilize nitrogen during storage.

In Northern Cameroon, on-farm trials were, therefore, conducted to determine the effect of manure on maize yield. Yield increase was significant with the application of 5 tons/ha manure in combination with 25 kg N/ha (OAU/STRC-SAFGRAD FSR Tech. Report, 1989). The beneficial effect of manure on crop production is more pronounced during the second and third successive seasons. In trials in North East and West Benoue region of Northern Cameroon, treatments with animal manure (5 ton/ha) in combination with commercial fertilizer (25 or 50 kg N/ha) gave higher net profit during second and third years. The three years' result (Fig. 5) showed that the treatment with 5 tons/ha manure plus 25 kg N/ha had an overall higher marginal rate of return compared to the others (Ngambeki, 1989). A 5 ton/ha of animal manure is reported to supply 100 kg N, 17.5 kg of phosphorous and 50 kg potassium/ha (Donahue *et al.*, 1977).

Table 2. The effect of different levels of agronomic practices on the grain and stover yields of sorghum and millet in Sudan and Sudano-Sahelian zones of Burkina Faso.

Management practice[a]	Village					
	Kamsaoghin (Rainfall, 820 mm)		Yalka (Rainfall, 674 mm)		Kamsi (Rainfall, 875 mm)	
	Grain yield (kg/ha)	Stover yield (tons/ha)	Grain yield (kg/ha)	Stover yield (tons/ha)	Grain yield (kg/ha)	Stover yield (tons/ha)
1. Levels of sorghum management:						
i) Tied ridging + fertilizer	1766	5.5	507	3.0	1447	6.7
ii) Mulch + fertilizer	1818	6.9	880	5.0	1947	8.0
iii) Traditional practice	694	3.3	372	3.2	881	2.2
iv) Fertilizer alone	2688	5.7	726	4.5	1637	5.5
LSD at 0.05 level	411	1.1	689	2.4	680	2.9
2. Levels of millet management:						
i) Tied ridging + fertilizer	1382	7.6	700	1.7	396	1.9
ii) Fertilizer alone	1099	6.9	250	1.2	476	2.2
iii) Traditional practice	796	5.8	450	0.99	99	0.800
LSD at 0.05 level	234	0.59	178	0.62	105	0.34

a: Tied ridging, a water-soil retention technology, was constructed one month after planting.

Fertilizer was applied at the rate of 100 kg/ha NPK (14:23:15) + 50 kg/ha urea. Mulch was applied at the rate of 5 tons/ha.
Source: Kibreab T. (1989).

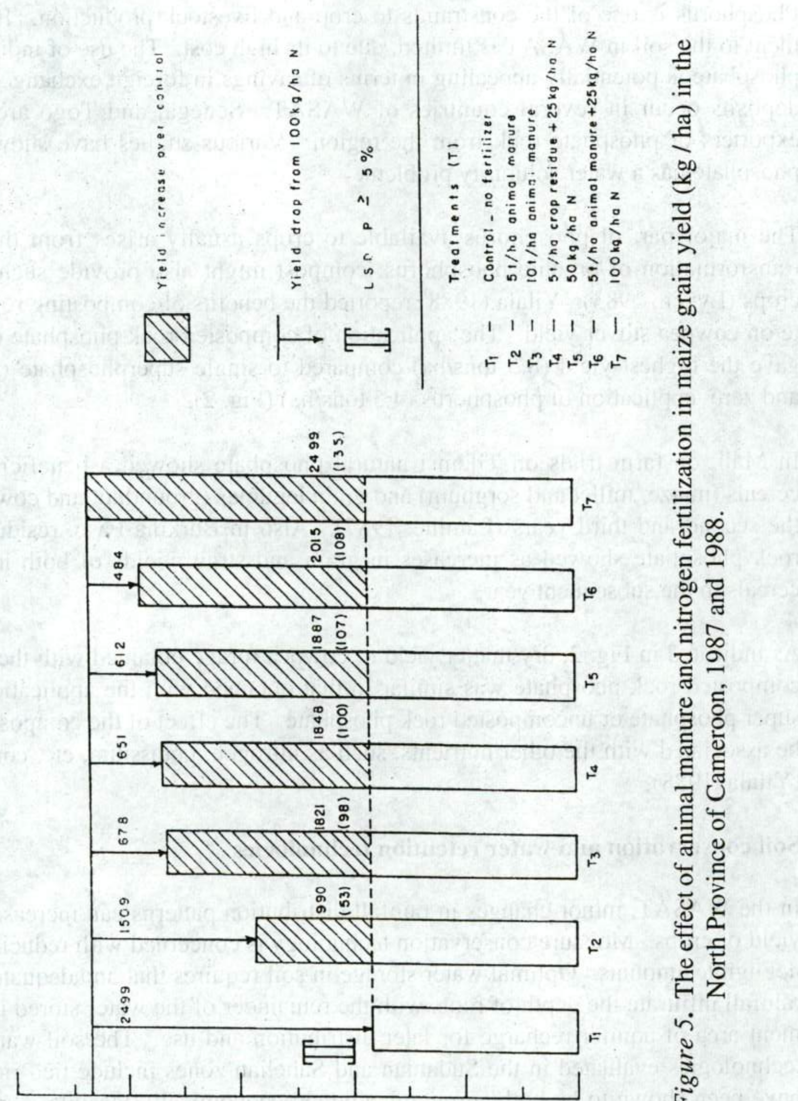


Figure 5. The effect of animal manure and nitrogen fertilization in maize grain yield (kg / ha) in the North Province of Cameroon, 1987 and 1988.

In the sub-humid zone of Nigeria, on-farm trials conducted inside and outside pastoralist owned and managed fodder banks revealed that the yield of maize planted in the fodder banks nearly doubled that on natural fallow (Tarawali *et al.*, 1989). In general, manure application and rotation of cereal (following forage or grain legume) could substantially reduce commercial fertilizer N requirements of cereal crops.

iv) Use of indigenous rock phosphate/compost

Phosphorus is one of the constraints to crop and livestock production. Its replenishment to the soil in WASAT is limited, due to its high cost. The use of indigenous rock phosphate is potentially appealing in terms of savings in foreign exchange, since large deposits occur in several countries of WASAT. Senegal and Togo are two major exporters of phosphate rock from the region. Various studies have shown that rock phosphate has a water solubility problem.

The major part of phosphorus available to crops usually arises from the microbial transformation of organic phosphorus; compost might also provide such benefits to crops (Lynch, 1983). Yilala (1988) reported the benefits of composting rock phosphate on cowpea stover yield. The application of composted rock phosphate (400 kg/ha), gave the highest yield (8.5 tons/ha) compared to single superphosphate (7.0 tons/ha) and zero application of phosphorus (4.5 tons/ha) (Fig. 2).

In Mali, on-farm trials on Tilemsi natural phosphate showed a beneficial effect on cereals (maize, millet and sorghum) and grain legumes (groundnut and cowpea) during the second and third years (Lamine, 1987). Also in Burkina Faso, residual effect of rock phosphate showed as increases in grain and straw yields of both legumes and cereals in the subsequent year.

As indicated in Fig. 2, dry matter yield of cowpea forage obtained with the addition of composted rock phosphate was similar to that obtained with the application of single super phosphate or uncomposted rock phosphate. The effect of the compost might also be associated with the other nutrients, such as nitrogen, potassium, etc. contained in it (Yilala, 1988).

Soil conservation and water retention technologies

In the WASAT, minor changes in rainfall distribution patterns can increase or depress yield of crops. Moisture conservation technology is concerned with reducing runoff to negligible amounts. Optimal water storage in soil requires that an adequate amount of rainfall infiltrate the depth of roots with the remainder of the water stored in the catchment area of aquifer recharge for later distribution and use. The soil-water retention technologies evaluated in the Sudanian and Sahelian zones include tied-ridges, which have been shown to be both agronomically and economically feasible. According to Hulugalle (1987), tied-ridges (TR) also improved the physical properties of the soil, by increasing the surface clay contents on ridges and furrows. Soil chemical properties of TR (increased levels of soil organic matter, exchangeable Ca, Mg, K and total cation exchange capacity) were superior to those of open ridges. The effectiveness of TR depends on numerous factors (e.g., nature of soil, position on toposequence, date of ridging after planting and distance between ridges). Perrier (1987) working in the Sudanian zone of Burkina Faso with sorghum and millet, showed yield increases from 100 to 200% due to tied-ridges combined with mulch.

Integrating livestock production into cropping systems

Livestock production is an important economic activity in WASAT. The qualitative and quantitative improvement of the natural pasture in fallow land could enable farmers to sustain limited livestock production in general and small ruminants in particular.

The utilization of draught power is unavoidable at the current stage of development. It will not only reduce the drudgery of labour but will also allow intensification of the production system through increased efficiency of labour. Drought power is required for soil and water conservation measures (such as, tillage, and building of tied and contour ridges) and for the transportation of crop residues and other feedstuffs to animal enclosures, and of organic manure or compost to the fields. Most of these activities are expected to occur before the rains when the animals are usually in poor condition for draught work. The traditional feeding system is barely sufficient to maintain even the live weight of the animals, mainly due to the low energy and nitrogen intakes. It is recognized that the physiological nutrient demand for body maintenance and draught power can only be satisfied when the nutritional factors limiting intake are removed and adequate levels of nutrients are supplied. Under the prevailing condition, this could be achieved by supplementing the fibrous basal diets for livestock with a source of nitrogen.

In the Sudanian zone of Burkina Faso, there is heavy reliance by farmers on small ruminants, particularly sheep, for immediate cash and as a source of meat. Although farmers prefer to keep small ruminants because of relative ease of management and less feed requirement, their productivity is also constrained by inadequate availability of feeds. Farmers have not given due importance to the incorporation of forage crops into their crop production systems. As a result, there is a mismatching of supply of nutrients and demand for the various physiological performances of animals. This study explored the following possibilities to qualitatively and quantitatively improve the natural pasture: (a) conservation of natural hay at the right stage of growth, (b) replacement of poor fallow pasture with forage legumes or establishment of perennial legumes into the natural pasture, (c) intercropping cereals with dual-purpose grain or forage legumes and production of browses along contour bunds, and (d) silage making as feed supplement during the dry season.

The best time for the conservation of natural pasture as hay under the prevailing farm conditions in Burkina Faso was determined to be mid September when labour requirements for other farm activities subsided. An average hay yield of up to 4.5 tons/ha was harvested. Harvesting of the natural pasture at the appropriate stage of growth also improved its digestibility when fed with forage legumes. In order to improve the quality of natural pasture on fallow land, *Stylosanthes hamata* and *M. atropurpurium* were oversown. *S. hamata* established densely in its regrowth in the subsequent rainy season (after passing through the dry season). This makes it suitable for growing in mixture with grass to improve the natural pasture. Multi-purpose shrubs and trees which could partially supplement forage needs include *Bauthenia rufescence, Prosopis juliflora, Parkinsonia aculeata, Acacia trachycarpa* and *Combertum aculeata.*

The limited observations made on pigeon pea (*Cajanus cajan*) planted on contour bunds indicated that it could be established to provide substantial amounts of biomass; it remained green until the end of December, three months after the end of the rainy season. Prunings from pigeon pea plants were conserved as hay or fed fresh as a source of nitrogen supplement with the native pasture hay or cereal crop residue during part of the dry season. Pruning of pigeon pea before or immediately after cereal harvest was necessary so that it could be saved from free ranging ruminants. Pigeon pea and other fast growing browses could be introduced successfully within the alley on cropping systems.

Cotton is the principal export crop in Burkina Faso. One of its by-products, cottonseed cake, is the cheapest amongst the purchasable sources of energy and nitrogen and could be used to complement forage legume supplements (Yilala, 1988). The benefits of inclusion of cottonseed cake in sorghum-based diet on live weight gain was accompanied with an increase in the contents of phosphorus in the faeces of sheep (Yilala 1989). The latter is of paramount importance to improvement of poor soil phosphorus status in the Sudanian zone of Burkina Faso.

In the Sudanian zone of Burkina Faso, trials have shown that both Djallonke and Bali Bali sheep were able to maintain their live weight when fed natural pasture hay (grass and legume) during the critical dry period between January and mid-May. This is a period when sheep and other domestic animals lose substantial amounts of their live weight. This demonstration encouraged cooperating farmers to grow forage legumes or dual-purpose crops such as *Vigna unguiculata*, *Lablab purpureus*, *Stylosanthes hamata*, *Phaseolus aureus*, etc. for livestock feed and for restoration of nitrogen in the fallow land. Crop residues of sorghum, maize and millet stover were also fed to livestock.

Conclusion

The recurrence of drought, the over exploitation of the resources of the specific agroecosystem without concurrent replenishment of the soil nutrients, the traditional perception of separate crop and animal husbandry (i.e transhumans nomadic herding and settled crop-growers), the rapid population growth, etc put stress on the land use patterns and intensity of cultivation.

Every year, not only millions of hectares of new land are brought under cultivation, but also resulted in the degradation of the rresource base to support productive and sustainable agriculture.

Traditional farming systems and modern agricultural practices, currently are subject to modification or to a complete overhaul, in oder to resolve both environmental degradation problems and agrarian crisis in sub-Saharan Africa.

The building of soil organic matter is crucial to enhance the development of sustainable agricultural production systems. Integration of the sub-systems of agricultural production is the pathway to enhance the development of sustainable agriculture, with concurrent rejevunation of the resource base. Qualitative and quantitative improvement of animal feed production could lead to resources cycling and economic complementarity among farm enterprises.

Crop residue, if efficiently managed, not only coul be used for animal feed, for fuel and construction purposes; but can reduce rainfall runoff, to eventually improve infiltration of water into the soil. Scarcity of mulching material in the sudan and sudano-sahelian zones could be overcommed in the increase of biomass or stover production of cereals, grain and forage legumes through improved agronomic practices.

By improving the quality and productivity of the natural pasture, livestok can be integrated into crops based farming systems. The overall farming objective for integration of crop/livestock production system is also to convert the abundant cellulosic energy in crop residues and the natural pasture into high marketable product such meat and milk; into farm power through animal traction; and to enhance the recycling manure organic matter nitrogen (N) and other utrients for the improvement of soil structure and fertility essential for the cultivation of crops. Forage legumes serve also, as key between crops and animals, through biological N_2- fixation and green manue source and supply of N for increased animal productivity.

The integration of agroforestry systems into rop/livestock enterprises is also of crucial importance. In addition to restoring and sustainance of soil fertility, leguminous shrubs coul provide quality forage for livestock and also contribute to the improvement of soil fertility and conservation. Furthermore, over 90% of families in WASAT, depend on wood fuel for cooking building materials as well as the generation of an income. With increasing deforestation and distance from villages women and children, spend considreable time in gathering wood. The integration of trees/corps/livestock enterprises on-farm, not only enhance the rejuvenation of the resource base, but also enable communities to meet the food, shelter and energy requirements of the increasing population.

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La Recherche Participative des Solutions Contre le *Striga*: Une Voie pour Améliorer le Niveau d'Autosuffisance Alimentaire en Afrique de l'Ouest

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Résumé

Au Sud du Sahara et particulièrement en Afrique de l'Ouest, les céréales et le niébé occupent une place importante dans l'alimentation humaine. Ces cultures sont cependant limitées dans leur productivité par le *Striga* qui infeste des milliers de superficies, causant ainsi des pertes de rendement allant de 10% à 100%. Bien que beaucoup de technologies aient été développées par la recherche, leur adoption reste assez faible alors que le problème s'amplifie progressivement. La plupart de ces technologies sont exigeantes en temps de travail et en argent correspondant peu aux pratiques de gestion des cultures céréalières, du niébé et le point de vue des paysans, leurs connaissances et leurs pratiques sont insuffisamment pris en compte par les chercheurs et les développeurs, ce qui constitue une contrainte.

Dans ce cadre, l'ESPGRN de Sikasso au Mali a développé une approche participative qui permet d'appréhender ces aspects. L'approche se base sur l'analyse du problème de concert avec les paysans à plusieurs niveaux : (1) le terroir villageois, (2) l'exploitation agricole et (3) la parcelle. Elle s'applique à l'aide des outils participatifs et visuels comme (1) la carte du terroir villageois (2) le transect, (3) la catégorisation paysanne et (4) la carte de champs.

Les résultats des recherches participatives exécutées dans deux zones distinctes, montrent que le degré (1) d'infestation du *Striga* et (2) de connaissances et pratiques paysannes par rapport au problème diffère sensiblement entre les zones et les exploitations. L'histoire de l'occupation des terres, le type de sol, la toposéquence, l'intensité de l'érosion et la transhumance sont des facteurs dans la répartition inégale du *Striga* à travers le terroir villageois. Les principales pratiques paysannes de lutte contre le *Striga* sont : (1) l'utilisation des variétés tolérantes, (2) l'application de l'urée, (3) les semis précoces et (4) les sarclages et buttages. Leur degré d'application est fortement influencé par les conditions socio-économiques et objectifs de production des exploitations.

L'expérience montre que le diagnostic participatif permet de mobiliser les paysans pour des actions collectives et individuelles de lutte contre le *Striga* en fonction de la spécificité du terroir villageois et des exploitations.

Abstract

In Sub-Sahara, cereals and cowpeas constitute a major share in human diet. The productivity of these crops however is limited by *Striga* which infests thousands of acreages causing yield losses of 10 to 100%. Although many technologies have been developed by research, their adoption remains quite low while the problem is gradually increasing. Most of these technologies are demanding working time and money which do not correspond to the management practices for cereal crops and cowpeas. The gap is that the point of view of farmers, their knowledge and their practices are inadequatly taken into account by scientists and developers. In this context, Sikasso ESPGRN in Mali has developed a participatory approach by which these aspects can be handled. This approach is based on the joint analysis of the problem with farmers at various levels: (1) the village territory (2) the farm and (3) the plot. It is applied with participatory and visual tools such as (1) the map of the village territory (2) the transect (3) farmer categorization and (4) fields map.

The results of participatory research conducted in two distinct zones indicate that the extent of (1) *Striga* infestation and (2) farmers knowledge and practices in relation to the problem substantially differs between the zones and farms. The history of land occupation, the type of soil, the toposequence, the intensity of erosion and transhumant cattle crossing are factors in the unequal distribution of *Striga* through the village territory. The major farmers practices to control *Striga* are: (1) the use of tolerant varieties (2) the application of urea, (3) early planting and (4) weeding and ridging. The extent of implementation of these practices is highly influenced by the socio-economic conditions and the production objectives of the farms.

Experience shows that with participatory diagnosis, farmers can be mobilized for collective and individual actions against *Striga* according to the specificity of the village territory and farms.

Introduction

Le *Striga* est l'une des adventices les plus redoutables reconnues par les paysans de la zone Sub-Saharienne. Dans la zone cotonnière située dans le sud du Mali, le parasite constitue de plus en plus une véritable contrainte pour les cultures vivrières comme le mil, le maïs et le niébé. Au Mali, 86% des superficies infestées sont occupées par *Striga hermonthica* qui est l'espèce parasite des céréales sèches (ICRISAT, 1992). Les dégâts vont de 10% jusqu'à la perte totale de la production (Smaling et al., 1991, Konaté et al., 1986).

Bien que plusieurs techniques de lutte soient développées dans les stations, leur adoption est restée très faible (Orgborn, 1984). Une des causes principales est que la plupart des techniques ne sont pas adaptées aux conditions socio-économiques locales (Smith, 1992). En plus, la recherche des solutions a été généralement faite sans prendre en compte les points de vue, les connaissances et les pratiques des paysans. L'envergure du problème nécessite d'être comprise à travers une analyse des états du milieu et des pratiques paysannes aussi bien au niveau terroir qu'au niveau exploitation et parcelle. Ainsi, il devient de plus en plus claire que la recherche de solutions à ce problème doit être faite avec une participation effective des paysans qui vivent quotidiennement le problème.

C'est ainsi que l'Equipe Systèmes de Production et Gestion de Ressources Naturelles (ESPGRN) de l'Institut d'Economie Rural (IER) au Mali a entrepris une recherche-action sur la lutte anti-*striga* en collaboration avec l'ICRISAT/WASIP-Mali et la participation active des paysans. Les objectifs spécifiques sont : (1) comprendre l'intensité et la diversité du problème de *Striga* (au niveau terroir et exploitation agricole), (2) identifier les connaissances et techniques paysannes de lutte contre le *Striga* et (3) identifier et mettre au point des méthodes de lutte efficaces et adaptées aux conditions spécifiques des paysans.
L'objectif final d'une telle recherche-action est de raisonner des décisions à prendre sur la lutte contre le *Striga* au niveau respectif du terroir villageois et exploitation agricole.

Méthodologie

La recherche-action a été conduite en équipe pluridisciplinaire composée de chercheurs (recherche système et thématique) et des vulgarisateurs de l'organisme de développement, la Compagnie Malienne pour le Développement de Textiles (CMDT). La démarche méthodologique, utilisant des techniques de la méthode Accélérée de Recherche Participative (MARP) inclut quatre étapes d'exécution qui totalisent 3 jours (Figure 1). Cette expérience s'est déroulée dans deux principales zones agro-écologiques du Mali, à savoir :

1) la zone Sud-Soudanienne (cas de Try II) et,
2) la zone Nord-Guinéenne (cas de N'Golopéné).

Les deux premières étapes se font au niveau village en vue de l'élaboration d'une carte de terroir, d'un transect à travers le terroir et d'un exercice de catégorisation des exploitations.

La carte du terroir villageois permet : (1) d'identifier et de localiser les différentes unités et éléments du terroir villageois (unités morpho-pédologiques, densité des exploitations, etc..., (2) de localiser la répartition du *Striga* dans le terroir et le degré d'infestation de *Striga* et (3) d'identifier les actions à entreprendre au niveau villageois. En plus, la carte du terroir permet de choisir le transect et de localiser les exploitations retenues pour des entretiens detaillés.

Le transect qui consiste à enregistrer l'ampleur relative du problème de *Striga* à chaque niveau permet de vérifier et de préciser les informations obtenues et de fournir des nouvelles informations en prenant en compte la variabilité du terroir.

La catégorisation paysanne relative à la maîtrise du problème de *Striga* permet (1) d'appréhender les critères paysans de différenciation entre les exploitations, et les causes sous-jacentes des différences et (2) d'identifier les groupes d'exploitations avec des pratiques de lutte et conditions socio-économiques semblables.

La troisième étape repose sur des entretiens individuels à l'aide des cartes de champs faites par les paysans.. Cela a pour objectifs (1) de visualiser les différents éléments du système de cultures en rapport avec la répartition et le degré d'infestation de *Striga*, (2) de comprendre les stratégies (dans le passé, présent, et avenir) en matière de gestion du

Striga dans le cadre structurel de l'exploitation et (3) de raisonner des actions de lutte pour mieux maitriser le problème du *Striga*.

La dernière étape consiste en une restitution des résultats des deux premiers jours. A ce niveau, des recommandations spécifiques seront élaborées avec les paysans et les points qui ne sont pas clairs rediscutés. L'équipe de chercheurs fournit aux paysans, la connaissance et l'information complémentaire afin de faciliter la phase d'identification et de planification des actions de lutte contre le *Striga*.

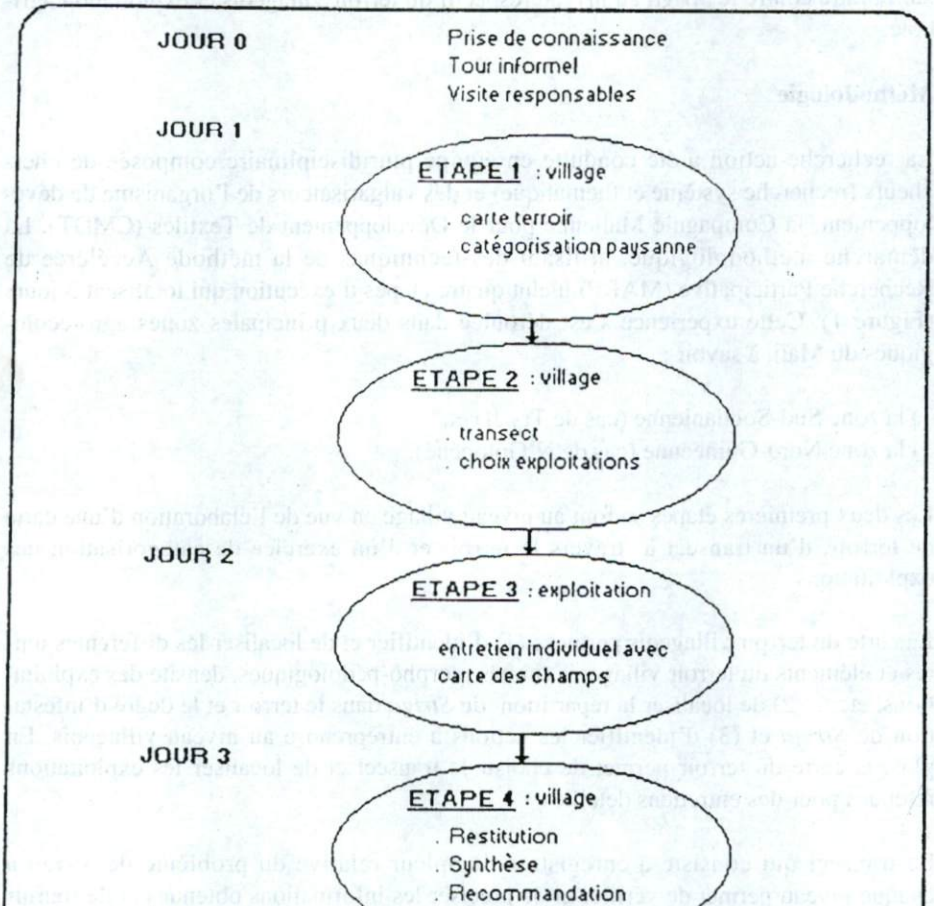

Figure 1 : Description de la démarche méthodologique

Caractéristiques de la zone d'étude

L'ESPGRN couvre la région administrative de Sikasso du Mali-Sud. La région est subdivisée en deux zones agro-écologiques : la zone Sud-Soudanienne dans le nord et la zone Nord-Guinéenne dans le sud. Dans chacune des deux zones, un village représentatif a été sélectionné pour l'étude : Try II dans la zone Sud-Soudanienne et N'Golopéné dans la zone Nord-Guinéenne.

Le climat de la région est caractérisé par une seule saison pluvieuse. La pluviométrie est de 800-900 m dans le nord et plus de 1000 mm dans le Sud. Suivant les toposéquences, les terres peu fertiles et peu profondes se trouvent sur les plateaux et versants tandis que les terres fertiles et humides se trouvent sur les bas glacis et les bas-fonds.

Dans la zone Nord-Guinéenne, (Tableau 1), la croissance démographique est relativement faible, influencée par les possibilités d'émigration vers la Côte d'Ivoire. Les systèmes de cultures sont basés sur des rotations à dominance céréalière, suivies de longues périodes de jachères grâce à une grande disponibilité de terre cultivables. L'introduction de la culture de coton est assez récente. Bien que l'élevage fasse partie du système, il est très peu intégré à l'agriculture : l'alimentation des animaux reste encore beaucoup liée aux pâturages naturelles. L'agriculture est peu intensifiée et la production de fumure organique est faible.

Tableau 1 : Population, terre et niveau d'intensification dans les deux zones

	Zone Sud-Soudanienne (Nord)	Zone Nord-Guinéenne (Sud)
Densité population (N/km^2)	13 - 49	11 - 22
Croissance population (%/an)	3.47	0.78
Terre cultivable (%)	55	73
Terre cultivée (% de la terre cultivable)	69	<20
Surface cultivée par exploitation (ha)	12	14
Utilisation fumure organique (kg/ha cultivée)	1646	463

Source : IER/KIT ; 1991 Profil d'environnement Mali-Sud

Dans la zone Sud-Soudanienne (Tableau 1), la culture de coton et la traction animale, combinées avec la croissance démographique accélérée ont engendré l'extension rapide des superficies cultivées. Le résultat est une occupation de plus en plus permanente de ces terres et à l'installation progressive sur des terres marginales. Le recours aux jachères permettant la reconstitution de la fertilite des sols est devenue exceptionnelle. Le maintient de la fertilité des sols nécessite des investissements importants afin de garantir leur productivité et de prévenir la dégradation. Le niveau d'intensification est assez élevé par rapport à la zone Nord-Guinéenne. Les exploitations qui ont plus de moyens produisent trois fois plus de fumure organique que celle de la zone Nord-Guinéenne.

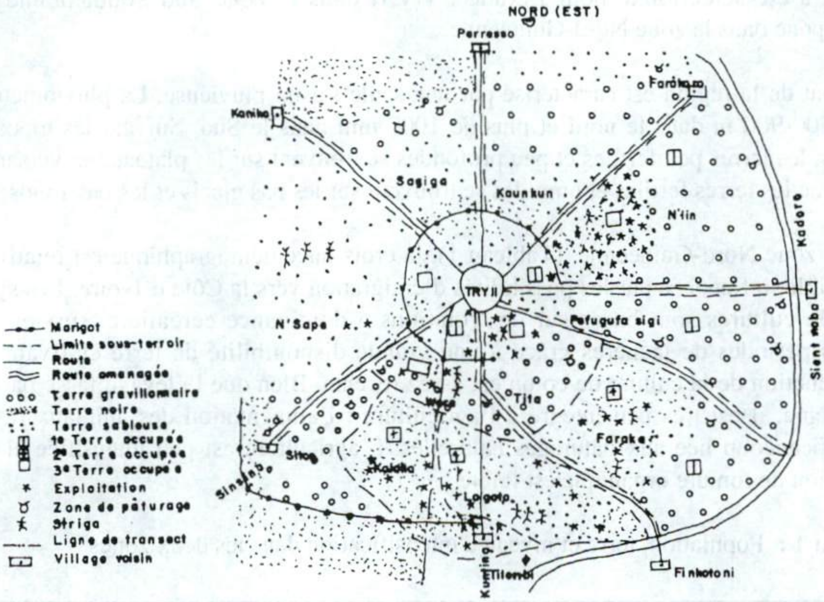

Figure 2. Carte terroirs de Try II

L'occupation des terres par les paysans a connu une certaine évolution dans le temps. Elle a commencé par les terres gravillonnaires (moins enherbées), suivie des terres noires (limoneuses et limono-sableuses, limono-argileuses) et enfin les terres sableuses. Les terres sableuses autour du village ont commencé à être cultivées en même temps que les terres gravillonnaires. La pluviométrie a diminué progressivement dans le temps alors que la population a augmenté pendant la même période. En conséquence l'éclatement des exploitations s'en est suivi, engendrant ainsi de véritables contraintes pour l'occupation agricole du terroir (Figure 2).

Selon les paysans, le striga s'observe partout dans le terroir mais avec des degrés d'infestation variables suivant les sites. Ils ont observé une relation entre le type de sol, le taux d'humidité du sol et le degré d'infestation du striga. D'une façon générale, les sols légers retenant peu d'eau sont les plus sensibles à la prolifération du striga. Ainsi, l'intensité du striga est beaucoup plus importante sur les terres sableuses dans ce terroir. Par contre, l'infestation sur les 'terres noires' est en général très faible. Les champs aux abords des marigots (bas-fonds) sont aussi très peu infestés.

Zone Nord-Guinéenne (cas de N'Golopéné). Le terroir villageois de N'Golopéné comprend six sous-terroirs qui sont : Siramatama, Batama, Gètama, Dongorotoma, Guinguèrètama et Genaha (Figure 3). Le sous-terroir Genaha qui est essentiellement constitué de collines n'est pas encore utilisé pour les activités agricoles.

Suivant la texture, les paysans ont identifié cinq types de sol : (1) gravillonnaire, (2) sableuse, (3) hydromorphe, (4) argilo-gravillonnaire, (5) noire (limoneuse et limono-sableuse). A part les terres hydromorphes, les autres types sont utilisés pour l'agriculture.

A cause de la grande disponibilité de terres cultivables, la durée d'exploitation des champs dans ce terroir est relativement courte (inférieure à 10 ans).

Les premiers champs ont été installés sur sols gravillonnaires dans le sous-terroir de Getama appartenant à la famille fondatrice du village. Les derniers champs ont été installés dans le sous-terroir de Guèguèrèdontama (argilo-gravillonnaire, et sableux) occupé surtout par des jeunes exploitations.

Trois sous-terroirs sont érodés (Gètama, Dongorotama et Siramatama) à cause essentiellement de la présence de petites collines. La présence de cours d'eaux est bien marquée dans la partie Est du terroir. Cela explique la présence fréquente des animaux sur les sous-terroirs de l'Est à la recherche de l'eau et de l'alimentation. Les paysans ont en effet mentionné cela sur la carte des zones de pâturage et de passage pour les animaux (bovins surtout) dans les sous-terroirs de Gètama et de Dongorotama.

Comme dans la zone Sud-Soudanienne, le *Striga* est rencontré dans tout le terroir mais le degré d'infestation est variable d'un site à l'autre. Il existe des sous-terroirs très infestés alors que d'autres ont des niveaux d'infestation très faibles.

Les paysans lient cette variabilité du *Striga* avec le type de sol en place. La texture gravillonnaire des terres est en effet perçue par les paysans comme un facteur qui influence beaucoup l'infestation. L'historique semble aussi avoir un rôle important. Le sous-terroir de Gètama essentiellement gravillonnaire et cultivé depuis l'installation du village connaît de nos jours la plus importante infestation du striga. En plus, le sous-terroir connaît le problème de *Striga* depuis le temps des ancêtres. Guinguèrèdontama a une faible infestation à cause de son utilisation très récente par l'agriculture (abritant les jeunes exploitations issues des éclatements).

D'autres facteurs qui pourraient également influencer le degré d'infestation du *Striga* incluent :

- le vent : les paysans supposent que les grands vents d'harmattan qui soufflent d'Est en Ouest peuvent bien entraîner les graines minuscules de *Striga* vers d'autres localités.
- les eaux de ruissellement : les paysans ont observé que les parties du terroir situées en aval d'une zone de *Striga* sont facilement infestées. Une relation a été faite avec les sous-terroirs les plus infestés où le ruissellement est très abondant.
- les zones de pâturage et de transhumance : pour les paysans la prolifération est possible à partir des bouses de vaches qui peuvent contenir des graines de *Striga.*

Il existe des différences entre les deux terroirs. Malgré une grande disponibilité de jachères, il existe encore dans la zone Nord-Guinéenne des agriculteurs qui exploitent des terres gravillonnaires. Par rapport à la zone Sud-Soudanienne, les bonnes conditions pluviométriques semblent encore favoriser de telles pratiques alors que la propagation du parasite serait plus rapide sur les sols gravillonnaires situées en amont des meilleurs terres agricoles.

Le terroir de Try II (zone Sud-Soudanienne) apparaît plus exploité par rapport à celui de N'Golopéné (zone Nord-Guinéenne) où malheureusement l'infestation est importante. Le bon niveau d'intensification agricole dans la zone Sud-Soudanienne occasionnée par l'agriculture commerciale du coton explique dans une certaine mesure de faible niveau d'infestation de *Striga* dans cette localité.

L'espèce de *Striga hermonthica* est la plus dominante dans les deux localités. Une absence de l'espèce *Gesneriodes* a été constatée à N'Golopéné probablement à cause du faible niveau de la culture du niébé (son hôte) dans cette zone.

A2) Niveau exploitation

L´outil catégorisation paysanne de la MARP a été utilisé pour identifier la diversité du problème de *Striga* entre les exploitations. Les variables qui expliquent les différences de degré d´infestation de *Striga* entre les exploitations peuvent être reparties en deux catégories: (1) les variables de gestion et (2) les variables structurelles de l'exploitation. Dans les deux zones, ces variables ont été identifiées et hiérarchisées comme suit (Tableau 2).

Tableau 2. Identification et hiérarchisation des critères de différenciation.

Variables	Rang	
	Zone Sud-Soudanienne (Try II)	Zone Nord-Guinéenne (N'Golopéné)
Variables gestion		
- Rotation	3	5
- Apport d'urée	2	2
- Fumure organique	1	-
- Variété (sorgho)	7	-
- Fréquence de labour	6	8
- Buttage	4	-
- Moment de sarclage	5	4
- Sarclage striga	-	1
- Semis précoces	-	
Critères structurels		
- Type de sol	*	3
- Age parcelle	*	-
- Disponibilité jachère	-	6
- Disponibilité charrette	-	7

Selon les paysans, les pratiques de gestion qui peuvent expliquer l'importance du problème de *striga* sont (1) l'application de la fumure organique, (2) la rotation, (3) le sarclage et (4) le buttage. La plupart de ces variables sont en réalité des méthodes de lutte contre le *striga* dont le niveau d'application peut expliquer le degré d'infestation dun champ par rapport à un autre.

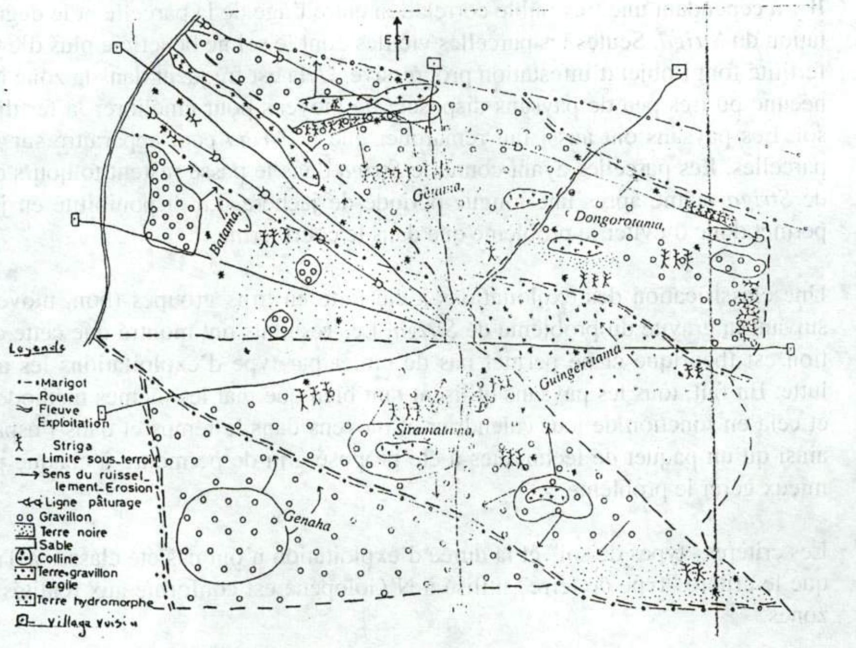

Figure 3. Carte terroir de N'Golopéné

Quelques différences existent entre les deux localités. La pratique de semis précoce a uniquement été identifiée dans la zone Nord-Guinéenne. L'urée n'est pas un critère pertinent dans cette même zone à cause de sa faible utilisation sur les céréales. L'utilisation de l'urée dans cette zone est aussi récente et essentiellement appliquée sur le coton. Les paysans n'ont pas encore découvert son effet sur le *Striga*. Lutilisation des variétés (de sorgho) résistantes au *Striga* n'a pas été jugée pertinente dans cette même zone, compte tenu de la priorité marquée qu'accordent les paysans au mil ou au maïs. Cependant les entretiens individuels ont montré une certaine utilisation de cette variété.

Les paysans ont identifié des variables liées à la structure de l'exploitation (ou des champs) qui peuvent expliquer des différences de degré d'infestation de *Striga* entre les exploitations. Bien que les paysans aient jugé le type de terre et l'âge des parcelles comme variables de "structure", ils n'ont pas jugé opportun d'utiliser ces variables dans le classement des exploitations dans la zone Sud-Soudanienne. La principale raison était que ces deux critères comptent actuellement peu dans les possibilités de gestion du *Striga*, étant donné la très faible disponibilité de jachères.

Dans la zone Nord-Guinéenne, par contre, la disponibilité de jachères joue sur l'importance de *Striga* dans la mesure où un exploitant qui a assez de terres disponibles peut plus facilement abandonner sa parcelle et défricher une autre. En plus, le type de sol et la possession de charette sont des éléments importants dans la maîtrise du *Striga*. L'importance de la charette s'explique surtout par son rôle essentiel dans le transport de la fumure organique.

Il y a cependant une très faible corrélation entre l'âge de la parcelle et le degré d'infestation du *Striga*. Seules les parcelles vieilles dont le sol ne bénéficie plus d'entretien de fertilité font l'objet d'infestation progressive. Cela est fréquent dans la zone Nord-Guinéenne où très peu de paysans disposent de moyens pour améliorer la fertilité de leur sol. Les paysans ont aussi fait remarquer que le *Striga* peut apparaître sur les jeunes parcelles. Les parcelles ayant connu le *Striga* dans le passé restent toujours des foyers de *Striga* même après une longue période de jachère. La disponibilité en jachère ne permet donc d'éviter le problème que dans le court terme.

Une classification des exploitations a été faite en trois groupes (bon, moyen, faible) suivant la gravité du problème de *Striga*. Les résultats ont montré que cette classification est théorique et ne permet pas de cibler par type d'exploitations les actions de lutte. En fait, tous les paysans utilisent tant bien que mal les mêmes méthodes de lutte et cela en fonction de leur calendrier et moyens dans le temps et dans l'espace. C'est ainsi qu'un paquet de techniques a été proposé afin de permettre à chaque paysan de mieux gérer le problème.

Les critères "types de sol" et la durée d'exploitation n'ont pas été classés à Try II alors que le critère "type de terre" utilisé à N'Golopéné est conforme aux réalités des deux zones.

B) Connaissances et pratiques des paysans

Les connaissances paysannes ont été identifiées sur la base des entretiens individuels à l'aide de la carte des champs. Un exemple de carte de champ est présenté au niveau de la figure 4.

Analyse de la carte du champ.

Le champ est situé à 5 km du village dans un domaine qui relève de la propriété foncière des parents du paysan.Il exploite cette partie du sous-terroir de Batama il y a plus de 30 ans. Il pratique un système de culture itinérant. La durée moyenne des parcelles exploitées est de 4 ans. Il produit du maïs, mil, sorgho, coton et igname suivant une rotation essentiellement céréales/céréales.

Il utilise rarement de la fumure organique sur les parcelles de coton à cause de la faible production de fumure et de l'insuffisance des moyens de transport. Les fumures minérales sont apportées sur les parcelles de coton et quelques rares fois sur celles du maïs.

Il existe assez de rigole dans son champ. Beaucoup de parcelles semblent connaître le problème de striga. Les parcelles les plus vieilles ou celles situées en bas de pente sont les plus infestées. Pour le paysan, cette situation s'explique essentiellement par le faible niveau de fertilité des vieilles parcelles et par les effets des eaux de ruissellement qui drainent les semences de *Striga* vers les parties avales dans son champ. Il pense même que cela pourrait contribuer à l'aggravation du problème dans le champ voisin situé plus bas.

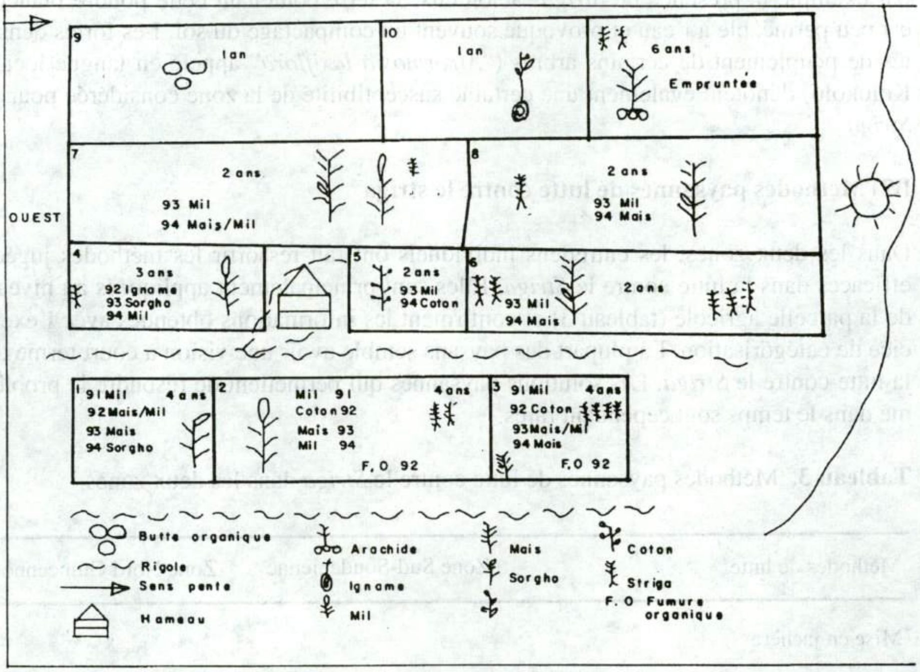

Figure 4 Carte de champ de Lamissa Ouattara : village de N'Golopéné (zone Nord-Guinéenne).

Après avoir analysé et discuté avec le paysan les solutions à envisager, il est ressorti la nécessité de (1) mettre des dispositifs anti-érosifs en amont et en aval des parcelles plus infestées et de (2) d'utiliser spécialement des méthodes de lutte appropriées telles que apport fumure organique, rotation coton/céréales et légumineuses/céréales, sarclage, etc...

B1) Connaissances paysannes sur la biologie du *Striga*

La connaissance des paysans sur la biologie du *Striga* n'est pas la même dans les deux localités. La biologie est très peu connue par les paysans de la zone Sud-Soudanienne alors que ceux de la zone Nord-Guinéenne ont des connaissances plus poussées. Ces derniers par exemple savent que le *Striga* produit des graines capable de germer, d'être propagées par le vent, l'eau de ruissellement et les animaux.
Dans les deux villages, les paysans ignorent le processus de parasitage du *Striga*. Ils savent cependant tous que le *Striga* attaque les cultures avant l'émergence, mais, ils ignorent l'existence de plusieurs espèces de *Striga*. Beaucoup de paysans croient que le *Striga* (même s'il n'apparaît pas) attaque le cotonnier. Les raison avancées sont que les cotonniers qui se développent sur les zones empreintes de *Striga* se comportent mal et l'éclatement de leurs capsules intervient très tôt par rapport aux autres parties du champ.

Les paysans ont des indicateurs permettant de déceler la présence du *Striga* même avant la mise en culture. La présence de tâches (poudres) blanchâtres sur le sol indique par exemple la présence de *Striga*. Selon eux, la terre contenant cette poudre blanche est peu perméable à l'eau et provoque souvent un compactage du sol. Les fortes densités de peuplement de certains arbres ("*Afrormosia laxiflora*" appelé en langue locale Kolokolo) dénotent également une certaine susceptibilité de la zone considérée pour le *Striga*.

B2) Méthodes paysannes de lutte contre le striga

Dans les deux zones, les entretiens individuels ont fait ressortir les méthodes jugées efficaces dans la lutte contre le *Striga*. Elles sont principalement appliquées au niveau de la parcelle agricole (tableau 3) et confirment les informations obtenues avec l'exercice de catégorisation. La plupart des paysans semble avoir une vision à court terme de la lutte contre le *Striga*. Les solutions paysannes qui permettent de résoudre le problème dans le temps sont cependant rares.

Tableau 3. Méthodes paysannes de lutte contre le *Striga* dans les deux zones.

Méthodes de lutte	Zone Sud-Soudanienne	Zone Nord Guinéenne
Mise en jachère		x
Rotations culturales	x	x
Fumure organique	x	x
apport urée	x	
buttage *Striga*	x	x
sarclage en temps humide	x	
travail limité sol	x	x
variétés tolérantes sorgho	x	
cendres végétales	x	
fientes chauve souris	x	x
semis précoce		x
sarclage *Striga*		

Dans le village de N'Golopéné en zone Nord-Guénéenne, une analyse des méthodes a été faite afin d'apprécier le rôle des paysans dans la lutte contre le *Striga.* Selon cette analyse, on peut classer les méthodes en deux groupes : celles qui entraînent une diminution progressive du problème d'une part, et celles qui favorisent l'augmentation des semences de *Striga* dans le champ d'autre part. Le tableau 4 résume l'essentiel de cette classification.

Tableau 4. Classification paysanne des méthodes de lutte (N'Golopéné).

Groupe 1 : Facteurs défavorable au *Striga*	Groupe 2 : Facteurs favorables au *Striga*
- mise en jachère	- fumure organique
- rotations culturales	- semis précoces
- fumure organique	- variétés tolérantes
- sarclage *Striga*	
- buttage *(Striga)*	
- le labour minimum du sol	

N.B. : Les solutions du groupe 2 permettent de réaliser de bons rendements mais favorisent en même temps une aggravation du problème de *Striga*, si les plants de *Striga* ne sont pas détruits avant fructification.

Discussion des Différentes Méthodes de Lutte

La mise en jachère: Elle est prépondérante dans la zone Nord-Guinéenne où les paysans disposent effectivement des jachères importantes. Dans cette zone, le statut foncier local fait que tous les paysans n'ont pas la même disponibilité de jachère. Les déclarations par les paysans dans les deux localités ont montré que la mise en jachère n'est pas une solution durable au problème de *Striga*. Ils ont observé que les anciennes parcelles de *Striga* mises en jachère pendant plusieurs années n'étaient pas épargnées du problème dès les premières années de remise en cultures. Cela apparemment pourrait être attribué à la remarquable tenacité du *Striga* ainsi qu'à la présence de *Striga aspéra* sur les jachères.

La fumure organique: Selon les paysans des deux zones, la fumure organique qui permet de réaliser de bons résultats limite les effets du *Striga*. Certains paysans ont même constaté une diminution progressive du nombre de pieds de *Striga* sur des parcelles recevant fréquemment de la fumure organique. L'absence des animaux, l'éloignement des champs, le manque de moyen de transport limitent cependant son utilisation au niveau de certaines exploitations. Le fumier toutefois peut être une source d'aggravation du *Striga*, si le paysan ne prend pas certaines dispositions. Par exemple, les fumiers produits en fin de la campagne agricole peuvent contenir des graines de *Striga* encore capables de germer. Ces fumiers deviennent ainsi une source d'infestation éventuelle pour les champs. Sur parcelles traitées en fumure organique, les paysans sont fréquemment 'emportés' par le bon comportement végétal des cultures bien que cela favorise aussi le développement du *Striga* qui éventuellement pourrait produire plus de graines et devenir ainsi une source plus tenace d'infestation.

L'urée: L'urée utilisée couramment sur toutes les cultures est considérée par les paysans de la zone Sud-Soudanienne comme un moyen efficace de lutte contre le *Striga*. C'est ainsi qu'une portion de cet engrais (en priorité destiné au cotonnier et maïs), est souvent déviée vers les parcelles de mil et de sorgho infestées par le *Striga*.

Les rotations culturales: A cause de l'intensification de la culture du coton dans la zone Sud-Soudanienne, la rotation culturale avec le coton est devenue une pratique courante. Les paysans qui ont choisi cette pratique pour mieux exploiter les arrière-effets des fumures ont observé une diminution du degré et des dégâts du *Striga* sur les parcelles concernées. Dans la zone Nord-Guinéenne, les paysans ont identifié principalement trois cultures après lesquelles l'infestation du *Striga* est relativement faible. Il s'agit du coton, l'arachide et le fonio. Une bonne efficacité a été surtout observée avec de fortes densités de fonio. Cependant, compte-tenu de certaines contraintes, ces rotations ne semblent pas toujours possibles au niveau du paysan.

Le buttage: Dans les deux zones, les paysans ont observé que le buttage tout juste en début d'émergence des plants pouvait provoquer la rupture du cycle biologique du striga. Toutefois, cette technique ne semble pas efficace sur le maïs, car les plants déjà affaiblis ne peuvent plus se développer avant la fin du cylce végétatif.

Le sarclage en temps humide: Les paysans de la zone Sud-Soudanienne ont observé que le sarclage des tâches de *Striga* pendant une poche de sécheresse favorise l'émergence du *Striga*. Des investigations toutefois sont à faire afin de confirmer ou infirmer ce lien de causalité.

Le sarclage des plants de *Striga*: Les paysans de la zone Nord-Guinéenne qui pratiquent le sarclage et l'arrachage des pieds de *Striga* sur les parcelles faiblement infestées ont constaté un effet positif de cette pratique sur les cultures de mil et de sorgho.

Le "labour minimum" du sol: Pour les paysans des deux localités, le labour est considéré comme un facteur de propagation et de dissémination du parasite. Afin donc de limiter les dégâts dûes au *Striga*, bon nombre de paysans pratiquent le semis direct du mil ou du sorgho à partir des anciens billons de cotonnier. Dans la zone Sud-Soudanienne où de grandes superficies de coton sont exploitées, cette pratique en effet se fait sans grandes difficultés.

L'utilisation de variétés tolérantes de sorgho: La variété tolérante de sorgho couramment appelée 'sèguètana' est cultivée sur les parcelles infestées. Cette variété (sèguètana) qui n'empêche pas totalement la poussée du *Striga* permet, toutefois, de réaliser de bons rendements. Le premier objectif du paysan étant des rendements, cette solution risque progressivement de provoquer une recrudescence du *Striga* dans les parcelles exploitées.

Semis précoces: Pour plus de sécurité alimentaire, les paysans de N'Golopéné font les semis précoces de céréales (maïs surtout) dès les premières pluies. Ils ont observé que grâce à cette pratique les rendements des variétés hâtives et intermédiaires de maïs étaient moins affectés par le *Striga*. Le danger, toutefois, de cette méthode est qu'elle augmente les graines de *Striga* dans le champ. Dans ce village, plus de 90% des paysans pratiquent néanmoins le semis précoce comme méthode de lutte.

Les cendres végétales: L'épandage des cendres végétales sur la parcelle infestée permet de réduire la densité de *Striga*. Toutefois, les paysans estiment que la faible disponibilité de ce produit par rapport aux superficies infestées limiterait son application.

Les fientes de chauve-souris: Quelques paysans de la zone Sud-Soudanienne rapportent avoir utilisé dans le passé avec succès les fientes de chauve-souris dans la lutte contre le *Striga.* Cet amendement est en général épandu ou enfoui dans les zones infestées du champ.

C) Identification et planification des stratégies de lutte

L'utilisation des outils participatifs et visuels pendant les deux premiers jours a permis aux paysans d'analyser le problème de *Striga* dans leur localité. Elle a aussi permis d'identifier les besoins d'information à fournir aux paysans. Le groupe de chercheurs a donné aux paysans d'amples informations sur la vie du parasite lors de la phase de restitution pendant le troisième jour du diagnostic. En plus, une séance de formation sur la reconnaissance des différentes espèces de *Striga* a été organisée. L'objectif de cette transmission de connaissances est de faciliter les propositions d'action du côté des paysans. C'est à partir de ces discussions que des stratégies définitives ont été arrêtées pour les campagnes à venir. Ainsi, le diagnostic participatif a permis de raisonner des actions adaptées aux conditions paysannes de chaque zone dans le cadre de la lutte contre le *Striga.*

Zone Sud-Soudanienne (Try II)

Le problème étant relativement maîtrisé, peu de mesures ont été préconisées pour cette zone.

Actions planifiées au niveau terroir: De nouvelles actions communales n'ont pas pu être proposées pour les raisons que voici : (1) le problème est relativement moins grave dans cette zone ; (2) il s'agit d'un village où beaucoup d'actions communautaires se font déjà. En fait, le village bénéficie depuis une dizaine d'années de l'encadrement d'un projet de lutte anti-érosive et fait partie d'un groupe de six villages qui se sont organisés pour une gestion commune de leur terroir.

Actions planifiées au niveau de l'exploitation agricole et individuelle (parcelle): Principalement, deux mesures applicables au niveau de l'exploitation agricole ont été identifiées et recommandées par le groupe des paysans :

(1) Utilisation d'une variété de niébé résistante comme moyen de lutte sur les parties infestées.
(2) Utilisation de l'urée sur les sols sableux afin de mieux maîtriser ou contrôler l'impact des parasites sur les cultures.

Zone Nord-Guinéenne

L'ampleur du problème, le bon niveau de connaissance des paysans sur la vie du striga, ont justifié une gamme d'actions à entreprendre aussi bien au niveau de l'exploitation agricole que du terroir villageois.

Actions planifiées au niveau du terroir: (1) Le village s'est mis d'accord pour réaliser des actions communales de lutte Anti-Erosive au niveau des zones de transition entre les terres gravillonnaires infestées en amont et les terres en aval dans les sous-terroirs les plus infestés. Elles débuteront dans le sous-terroir de Gètama (voir Figure 3). En fait, ce sous-terroir est le plus érodé en même temps qu'étant le plus infesté. (2) Les paysans ont aussi décidé que toutes pratiques qui favoriseraient une augmentation du stock de graines de *Striga* soient interdites sur les sols gravillonnaires qui sont en amont des bonnes terres agricoles.

Actions planifiées au niveau de l'exploitation et de la parcelle individuelle:

(1) Les animaux se nourrissent des résidus de récoltes entre Octobre et Janvier. Pendant cette période, les graines de *Striga* peuvent être avalées par les animaux et contaminer ainsi les fumiers produits. Sur leur passage et dans les parcs, ces déjections sont déposées par les animaux. L'action a entreprendre à ce niveau est que les fumiers produits entre octobre et janvier soient décomposés dans des fosses fumières afin de minimiser au maximum les effets dûs aux graines de *Striga.*

(2) Il a été aussi proposé d'améliorer le système de rotation culturales en intégrant les cultures 'pseudo-hôtes' (coton, arachide, niébé, fonio). Ainsi les associations avec les légumineuses couvrant bien le sol ont été jugées très utiles, notamment sur les poches d'infestation du *Striga.*

(3) Déjà sur les jachères, les paysans ont des indicateurs leur permettant de déceler la présence du *Striga*. Par contre, une stratégie similaire devrait être mise en oeuvre pour les parcelles nouvellement défrichées. C'est ainsi qu'il a été jugé très utile de commencer la culture des nouvelles parcelles (dans les zones suspectes) avec une utilisation intensive des cultures pseudo-hôtes. L'exemple suivant a été donné: 1ère année: légumineuse; 2ème année: coton; 3ème année: céréale + légumineuse.

(4) La fumure organique a été bien appréciée dans la lutte contre le *Striga*; malheureusement, les quantités produites dans ce village restent en deça des besoins, compte tenu de l'insuffisance de moyens de transport et des animaux. Afin de palier à ces deux contraintes, une alternative en vue d'accroître la production de la fumure organique consisterait à produire de la fumure dans des compostières placées non loin des champs.

(5) Le semis précoce est la méthode la plus pratiquée par les paysans de la zone. Il permet de réaliser de bonnes récoltes. Toutefois, cette pratique a l'inconvénient de produire plus de graines de *Striga* chaque année sur les parcelles. Ainsi, il a été décidé de concert avec les paysans de ne plus pratiquer le semis précoce comme seule méthode de lutte. Pour être plus efficace, le semis précoce devrait être associé à d'autres méthodes. Par exemple, un test de lutte intégrée associant semis précoce au sarclage, ou semis précoce+sarclage+buttage comparé à un témoin semis précoce seul a été préconisé pour la campagne à venir.

(6) Le test suivant a été aussi programmé pour la campagne à venir. Il s'agit des associations de légumineuses/céréales avec plusieurs niveau de densités pour la légumineuse:

a) sorgho tolérant + niébé (avec une densité 1) ;
b) sorgho tolérant + niébé (avec une densité 2) ;
c) témoin sorgho tolérant ;

(7) Par rapport à l'utilisation des cultures pièges dans la lutte contre le *Striga*, une opportunité est à saisir dans cette zone. Le repiquage du mil qui est une pratique courante sur les buttes rondes est réalisé en fin Août. La période de fin Mai à Août peut être ainsi mise à profit pour développer des plantes pièges. Comme exemple, des densités fortes de maïs pourraient stimuler la germination de beaucoup de graines de striga. Les plants de maïs et de *Striga* seraient enfouis dans des buttes rondes destinées au repiquage du mil.

Parmi les autres recommandations complémentaires, il faut retenir:

(1) La formation et sensibilisation sur la biologie et les effets du *Striga* au niveau de toutes les exploitations agricoles du village. Les paysans ayant déjà acquis des connaissances dans ce domaine ont été chargés de cette responsabilité.

(2) La formation d'un comité permanent de réflexion sur l'évolution de l'ampleur du *Striga* dans le village. Ce comité aura essentiellement pour tâches:

- d'observer et estimer l'ampleur du striga en cours et fin de campagne.
- de formuler et proposer des conseils aux autres paysans pour la nouvelle campagne.
- d'organiser des 'journées *Striga*' au niveau du village.

Conclusion

La recherche des solutions au problème de *Striga* doit être entreprise avec une participation effective des paysans. L'utilisation de différents outils méthodologiques de la MARP a permis d'appréhender l'ampleur du problème à différents niveaux. Du niveau terroir au niveau exploitation agricole et parcelle individuelle, la méthodologie a permis de mieux comprendre la dimension du problème en fonction de la zone agricole et en fonction du type de terroir et d'exploitation agricole. Cela a aussi permis d'identifier des actions concrètes de lutte contre le *Striga* à différents niveaux.

Le problème de *Striga* semble moins grave dans les localités où le système agricole est plus intensif avec une bonne utilisation de la fumure organique et des pratiques de rotations culturales variées. Par contre, les sols à texture légère, les anciens sites de champs infestés, les zones de pâturage intensif sont principalement les lieux où l'impact du *Striga* est le plus remarqué.

La longue durée d'exploitation d'un champ entraîne une augmentation du degré d'infestation du *Striga* surtout lorsque le sol ne bénéficie pas d'entretien organique. La gestion interne des parcelles au niveau d'une exploitation est en étroite liaison donc avec le degré d'infestation du *Striga*. En conséquence, la mise en jachère n'est pas une solution efficace dans le temps.

L'utilisation de moyens visuels pour le diagnostic du *Striga* permet de mieux définir et orienter les activités de recherche et de vulgarisation. Les efforts sont ainsi mieux ciblés. Dans le futur, la formation des paysans sur la biologie du parasite devra être considérée comme une priorité au niveau de la vulgarisation. Un diagnostic avec des outils participatifs serait notamment nécessaire avant l'élaboration des plans d'actions.

La recherche de son côté doit s'investir pour fournir à la vulgarisation les éléments nécessaires à la formation des paysans. Des informations doivent aussi être périodiquement fournies à la vulgarisation et aux paysans sur le *Striga* et ses mécanismes d'infestation.

La méthodologie a cependant quelques défaillances, les actions individuelles n'ayant pas pu être ciblées par type d'exploitation. Les différents outils méthodologiques utilisés ont certes permis de ressortir les informations essentielles mais la méthodologie mérite d'être encore testée dans une autre zone pour plus d'efficacité et une meilleure validation des résultats.

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Production et Utilisation de la Fertilisation Animale chez des Agro-pasteurs en Zone Subhumide du Burkina Faso et de la Côte d'Ivoire: Introduction de Quelques Innovations

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Résumé

Plusieurs innovations techniques concernant la fertilisation animale ont été essayées avec des agropasteurs de la zone subhumide de Côte d'Ivoire et du Burkina Faso dans le but d'optimiser la quantité et la qualité de la fumure pouvant être produite sur leurs exploitations : épandage de poudrette et parcage des animaux ; utilisation de tiges de cotonnier et de maïs.

Les effets de ces différentes techniques de fertilisation ont été observés sur les rendements de cultures de maïs. Des faits majeurs apparaissent : supériorité de la technique par parcage sur celle par épandage grâce à un meilleur apport azoté (rendements doubles); bonne qualité du fumier produit avec les tiges de cotonnier malgré une décomposition plus lente qu'avec les tiges de céréales (rendements égaux); production significative de fumier (12 tonnes).

Ces chiffres montrent que la production de fumier sur l'exploitation présente un intérêt majeur dans le contexte de la récente dévaluation du FCFA qui a renchéri le coût des intrants: elle valorise la rentabilité du cheptel bovin naisseur de façon importante et assure une certaine autonomie à l'exploitation.

Mots clés = Fertilisation animale/proudrette de parc/fumier/pailles de cultures ou de brousse/Transfert de technologie et système d'élevage.

Abstract

Several innovations related to animal fertilization have been tried with agropastoralists in the sub-humid zone in order to optimize the quantity and quality of the manure produced on their farms: These include broadcast application of manure, corralling of cattle, the use of cotton stems and maize straw on the land to be cultivated.

The effects of these various fertilization techniques on maize yield were observed. Among these fertilization techniques, better maize yield was obtained with corralling of cattle. In spite slower decomposition better quality of manure was produced with cotton stems than cereal straw.

These studies show that manure production on the farm offers a major interest in the context of the recent CFA devaluation which has increased the cost of inputs. It valorizes significantly the profitability of cattle and ensures some autonomy to the farm.

Introduction

Si l'avantage de la fertilisation animale est bien perçu par les paysans, il est clair que les modes de production et d'application sont susceptibles d'amélioration. L'efficacité de la fertilisation animale dépend en effet des technologies mises en oeuvre.
Par ailleurs, les conditions économiques de la fertilisation avec des engrais chimiques sont de plus en plus mauvaises et les effets de la récente dévaluation du franc CFA ont aggravé cette tendance.

Suite à l'insuffisance caractéristique des apports en engrais minéraux sur les cultures vivrières (de même pour le coton), on assiste de plus en plus à une baisse de fertilité due à la chute du taux de matière organique, à la destruction de la structure des sols, à l'acidification, et finalement à des perturbations du rôle d'échange du complexe absorbant.

En outre, les sols tropicaux ferralitiques pauvres en humus, sont sensibles au lessivage pluvial et à l'érosion. Ce désavantage est aggravé par les pratiques d'exploitation des terroirs des paysans laissant pendant la saison des pluies les sols souvent à nu, sans dispositifs anti-érosifs ou autre mesures conservatoires (enfouissement des pailles ; sole fourragère ; etc).

Tout cela entre dans le processus de dégradation des sols tropicaux décrits par Siband (1974) et Pieri (1989) : ou bien les systèmes actuels restent en équilibre et les rendements sont faibles ou bien il s'intensifient (zone à forte densité de population ou à activité agricole intense) et on observe une dégradation de la fertilité et de la structure. Pour remédier à cela, les techniques culturales modernes n'ont pas toujours donné de résultats satisfaisants en raison de mauvaises conditions d'application, de leurs coûts et besoins en main d'oeuvre.

C'est dans ce contexte que le rôle de l'élevage est déterminant en raison de la possibilité qu'ont les herbivores à participer aux transferts de fertilité, particulièrement dans les systèmes d'élevage sédentaires en zone sub-humide (Berger *et al.*, 1987; Lhoste et Richard, 1993; Landais *et al.*, 1993 ; Zoumana et César, 1993).

Les paysans-éleveurs des zones cotonnières ont justement à leur disposition une source importante et 'gratuite' de fertilisants d'origine animale: poudrette de parc et fumiers.

Cette source est importante si on utilise un grand nombre d'animaux (pas seulement les boeufs de trait) et le maximum de biomasse non-apprêtée (broussailles, chaumes de céréales, et tiges de cotonniers). Elle paraît plus intéressante car elle est plus disponible, plus facile d'accès et en outre elle ne coûte presque rien financièrement au producteur. On doit souligner cependant l'existence de certaines contraintes : charges en main d'oeuvre supplémentaires ; risque de salissement des cultures; besoins d'infrastructures d'élevage nouvelles.

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Matériels et Méthodes

Une première série d'observations est faite par Berthodière et al. (1984) au nord de la Côte d'Ivoire à Féléguésankaha (près de Korhogo). Deux modes de fertilisation avec la poudrette de parc sont comparés : le parcage nocturne et l'épandage manuel.

Le parcage nocturne est réalisé avec un troupeau de charge connue pendant un an sur une parcelle mise en culture ensuite. L'épendage se fait à la main (pratique habituelle), en utilisant la poudrette récoltée sur une épaisseur de 10 cm dans un parc ayant reçu la même charge en bétail et pendant la même période que celui du lot parcage. Les bovins utilisés sont des taurillons baoulé, métissés de zébus et appartenant aux villageois. La charge animale moyenne a été de 30 UBT/ha. Cet essai a été réalisé en zone de savane arborée dans la région de Korhogo (Côte d'Ivoire) où l'intensité de l'exploitation agricole des jachères est forte.

Le maïs test est un hybride sensible à la fertilisation : variété CJB (composite jaune de Bouaké). Il a été fertilisé selon trois traitements distribués en carré Latin sur des parcelles d'une surface unitaire de 1 ha (3 au total) :

- Epandage manuel,
- Parcage nocturne,
- Témoin sans fertilisation.

Une deuxième série d'observations a été faite à Kourouma au Sud de la zone cotonnière du Burkina Faso (Province du Kénédougou) par Godet (1993) sur la production de fumier avec des tiges de cotonniers dans l'exploitation d'un agroéleveur.

L'exploitant cultive 25 hectares (10 de coton et 15 de céréales). L'effectif en bovins est de 31 têtes. Les animaux sont gardés en permanence au pâturage et stabulent la nuit.

La technique de production du fumier fait appel à tout le troupeau et à l'utilisation de tiges de cotonniers, habituellement brûlées. Les tiges après récolte sont stockées sur une aire à proximité du parc et soumises aux intempéries avant d'être utilisées comme litière.

L'étable est sommairement ouverte, ainsi l'eau de pluie percole et renforce l'action des fécès et des urines pour décomposer le matériel végétal. Le fumier produit a été utilisé dès la saison suivante des pluies (150-180 jours). Le fond de l'étable est légèrement surcreusé de 10-15 cm pour favoriser une macération des tiges dans le purin. Il a été divisé en 4 compartiments ou blocs de 6 m² chacun :

- Tiges de coton et de maïs entières,
- Tiges de coton et de maïs hachées,
- Tiges de coton hachées,
- Tiges de coton entières.

Résultats

On estime que les 38 taurillons de l'essai 'poudrette de parc' en Côte d'Ivoire ont permis d'obtenir 2000 kg de poudrette/animal. Les valeurs de rendement en maïs (var. CJB) selon le mode d'épandage montrent que la poudrette est un engrais minéral très efficace (Tableau 1).
L'augmentation de rendement en grain des parcelles fertilisées (parcage) fertilisés par rapport au témoin est de + 121 %. Un avantage significatif de la technique de production de la poudrette par parcage sur celle par épandage apparaît : l'avantage au niveau du développement végétal de la plante entière (38,3 %). Les productions ont des valeurs faibles : 900 kg/ha pour le lot témoin et 2350 kg/ha pour le lot 'parcage'.

Tableau 1. Rendement en maïs* selon le mode d'épandage (Féléguésankaha, 1984)

	Témoin **	Epandage	Parcage	ppds***
Rendement tiges + feuilles (Tms/ha)	1	1,7	2,35	0,46
Rendement en épis (Tms/ha)	0,961	1,878	2,128	0,67
Poids épis/chamues	0,60	0,82	0,67	-

* var. CJB / ** pas de fertilisation / *** plus petite différence significative (test t).

Dans le cas de l'essai 'fumier de cotonniers et de maïs' au Burkina Faso, 12 tonnes de fumier ont été produits en 180 jours (récolte en fin des pluies et épandage au début de la saison suivante) et avec 31 têtes, soit 387 kg de fumier/animal. Les valeurs de rendement en maïs selon la nature du fumier montrent que le fumier comportant 1/3 de tiges de coton est meilleur que celui fait avec des tiges de maïs (Tableau 2).

Tableau 2. Rendements * en maïs selon le type de fumier (Kourouma, 1994).

	Quantité utilisée (T/ha)	Rendements en épis (kg/ha)	Rendements en tiges (kg/ha)
Tiges coton et maïs entières.	28	6553	3828
Tiges coton + maïs hachées.	38	6379	6663
Tiges de maïs hachées.	35	5668	5175
Tiges de maïs entières.	38	5707	5497
Témoin (50 kg de NPK)	-	3747	3627

* rendements obtenus sur des parcelles de 1000 m².

L'augmentation de rendement en épis des parcelles fertilisées avec différents types de fumiers est de 75 % supérieure au témoins dans le meilleur des cas (tiges entières de coton et de maïs). Il n'y a pas de différence significative selon que les tiges soient entières ou hachées. Par rapport au fumier produit à partir de tiges de maïs seules, l'augmentation de rendement est au plus de 31,9 % (tiges hachées de maïs/tiges entières de coton + maïs).

Les teneurs en éléments fertilisants des fumiers produits à Kourouma (Tableau 3), indiquent une richesse moyenne et une forte teneur en potasse.

L'étable a coûté 80.000 FCFA en achats de matériaux. Le solde du compte d'exploitation de l'agropasteur pour la campagne 1991/92 est de 3 millions de FCFA, soit 120.000 FCFA/ha. Ce type d'innovation est donc rentabilisé en une année.

Tableau 3. Composition chimique en % de différents fumiers.

	Terre de parc*	Fumier de broussailles	Fumier de graminée s	Tiges coton et maïs entières* *	Tiges coton et maïs hachées* *	Tiges coton hachées* *	Tiges coton entières **
Azote	1,075	0,657	1,173	2,024	1,638	1,851	1,727
Potasse	0,37	0,24	0,37	3,37	2,34	2,41	2,38
Phosphore	0,37	0,4	0,54	0,66	0,54	0,54	0,45

* Zoumana et al., 1994 - ** Godet, 1993.

Discussion des Résultats

Dans l'essai réalisé en Côte d'Ivoire, les faibles rendements obtenus sont sans doute liés à une mauvaise répartition des précipitations de l'année 1983, spécialement au moment de la floraison mâle. Par comparaison, le rendement moyen relevé cette même année par la CIDT (Compagnie Ivoirienne des Textiles) chez des paysans encadrés de la région voisine de Napiéléodougou est 1,5 t/ha avec des conditions culturales comparables. Par ailleurs, une attaque de *Striga Hermonthica* a eu une influence globalement dépressive sur les rendements.

Dans la technique par parcage, l'apport d'urine améliore le bilan azoté et le développement de la partie végétative et le rendement. Indirectement, cette bonne nutrition azotée en favorisant la croissance de l'hôte (le maïs), lui aurait permis de résister au parasite - (P. Thalouan *et al.,* 1993). Toutefois, le parcage n'est réalisable que si on maîtrise la gestion du troupeau (par exemple, clôtures électriques dans l'essai).

Les quantités de fumier produites dépendent évidemment de la durée de présence des animaux et de leur nombre. Au Burkina Faso, Hamon (1972) cite une production annuelle de 4 tonnes par bovin et de 1,7 t pendant l'hivernage (Berger 1987). En Côte d'Ivoire, Zoumana et César (1993) obtiennnent avec du fumier de broussailles et de graminées des quantités comparables à celle observée à Kourouma: 1 tonne par animal en 150 jours.

Les teneurs en éléments fertilisants des fumiers reflètent la composition du matériel végétal et du substrat. Ainsi, les valeurs observées à Kourouma sont-elles plus élevées que celles de Féguélésankaha (Tableau 3). La teneur élevée en potasse serait due aux tiges de cotonniers et celles des autres éléments à des sols plus riches. Rermarquons que les résultats d'analyse n'expliquent pas entièrement la bonne qualité de ce type de fumier et les rendements qui ont été observés. La décomposition des tiges de cotonniers au bout de 150 jours n'était pas complète. Elle a pu s'achever dans la terre après enfouissement.

Le haut niveau de rentabilité économique de l'essai de Kourouma, curieusement, n'a pas suscité d'enthousiasme chez l'agropasteur qui n'a pas poursuivi cette expérience en 1994. Néanmoins, il a continué à produire du fumier à partir de tiges de maïs et de sorgho dans un parc non-couvert attenant aux cultures.

Conclusion

L'intérêt agronomique et économique des innovations testées est évident, surtout avec le contexte récent de la dévaluation du F CFA. La fumure organique est en fait pratiquée traditionnellement depuis longtemps dans la sous-région (exemple, les contrats de fumure Peuhls-sédentaires ; les Zériba des peuhls). La fabrication de fumier organique est très répandue également dans les exploitations cotonnières. Dans ce cas, le rôle de l'encadrement semble déterminant et la pérénnisation du thème ne semble pas acquise.

Des recherches et des enquêtes doivent être entreprises pour cerner davantage les conditions d'acceptation et de vulgarisation des thèmes en matière de fertilisation animale dans le contexte récent de la dévaluation et de dégradation de l'environnement. Certains aspects qui sont abordés ici doivent être repris non à l'échelle expérimentale, mais au niveau d'une opération limitée de vulgarisation.

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Soil Fertility Management for Sustainable Agricultural Production in Semi-Arid West Africa

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Abstract

The development and intensification of agricultural production are vital for economic growth and the alleviation of poverty in semi-arid West Africa (SAWA). Poor soil fertility and low use of organic and inorganic fertilizers are two of the most important constraints to increased agricultural productivity in the region. Intensive cropping without replenishment of soil nutrients has progressively depleted the nutrient base of most soils leading to reduced soil fertility, damaged soil structure, reduced water infiltration, and increased soil erosion by water and wind.

Soil fertility in the farming systems of SAWA can only be maintained through efficient recycling of organic materials such as crop residues and animal manure in combination with mineral fertilizers and suitable crop rotations. In particular, livestock need to be incorporated and managed more efficiently within the farming systems not only to improve agricultural productivity, but also to minimize the competition that arises between independent crop and livestock production activities.

This paper identifies and reviews a number of options that can be used to raise agricultural productivity and reduce resource degradation in SAWA.

Résumé

Le développement et l'extension de la production agricole constituent un facteur fondamental de la croissance économique et de l'atténuation de la pauvreté en Afrique Occidental semi-aride. L'on sait que le faible niveau de fertilité du sol et d'utilisation des engrais organiques et minéraux représente la plus grande contrainte à l'augmentation de la productivité agricole dans la région. La culture intensive pratiquée sans restauration de la fertilité a progressivement épuisé la base d'éléments nutritifs de la plupart des sols, ce qui s'est souvent traduit par la diminution de la fertilité du sol, la rupture de la structure du sol, la réduction de l'infiltration de l'eau et l'aggravation de l'érosion hydrique et éolienne.

Dans les systèmes de production de l'Afrique Occidentale semi-aride, la fertilité du sol ne peut être maintenue que par le recyclage effectif des matériaux organiques tels que les résidus de récolte et le fumier animal associés aux engrais minéraux et par les rotations. L'élevage en particulier doit être intégré et géré plus efficacement dans les systèmes de production, non seulement pour accroître la productivité agricole mais également pour minimiser les problèmes environnementaux qui résultent de la concurrence entre la production de cultures et la production animale non-intégrées.

Cette communication illustre à l'aide de résultats recueillis en station et en milieu paysan, un certain nombre d'options qui pourront être appliquées pour accroître le rendement agricole tout en freinant la dégradation de l'environnement en Afrique Occidentale semi-aride.

Introduction

The West African semi-arid region, consisting of areas lyng between 350-1000 mm annual rainfall isohyets, is a potentially important agricultural zone for both crop and livestock production. However, with relatively poor soils and an erratic rainfall pattern, agricultural productivity is low. These two natural constraints are compounded by a rapid increase in human population. Population growth is currently estimated at about 3.0% per year (World Bank, 1992).

In the past, at low population pressure, farmers shifted from a cultivated site to an uncultivated one to avoid significant decline in crop yields, thereby enabling the fields to regain their nutrient losses under natural regrowth. However, with rapid population growth, fallow periods have shortened. Continuous and intensive cropping without restoration of soil fertility have depleted the nutrient base of most soils. For many cropping systems in the region, nutrient balances are negative, indicating soil mining. A basic challenge to agricultural research is to arrest this trend.

The importance of the agricultural sector in the economies of the Sahelian countries suggests that agricultural productivity must be increased not only to avert future food crisis, but also to provide the engine for economic growth and poverty alleviation. Fortunately, many of the better endowed agricultural lands currently under cultivation are still producing food at yield levels far below their potential. Further, studies have shown that it is often the supply of plant nutrients, rather than rainfall, that limits land productivity in the Sahel (Bationo and Mokwunye, 1991; Bationo *et al.*, 1993). Thus, remedial measures include, among other things, active research on integrated plant nutrients management with efficient use of natural resources, such as the locally available agro-minerals, combined with recycling of plant nutrients from organic and inorganic sources, and rotations.

This paper is concerned with establishing strategies for appropriate soil fertility maintenance in semi-arid West Africa. It begins with a review of the physical and chemical characteristics of soils in semi-arid West Africa (SAWA), and discusses the role of livestock in nutrient cycling. It identifies available technologies for soil fertility maintenance and assesses their relevance in light of the climatic and socio-economic changes currently taking place in the region.

Fertility Status of Soils in Semi-Arid West Africa

Soil properties

The major soils of importance in the SAWA are Aridisols, Entisols and Alfisols. The

Aridisols and Entisols are mostly derived from eolian origin and the Alfisols from eolian origin and from granite, gneiss and sandstones. From a physical stand point, Nicou and Charreau (1985) reported that these soils are structurally very weak, have low porosity, are easily compacted (except for soils of eolian sediments), have low water holding capacities, and are very susceptible to both water and wind erosion. Raindrop impact results in breakdown of surface aggregates, leading to the formation of surface crusts and subsequent reduction in water infiltration rate which in turn increases water run-off and soil erosion during the high intensity rainstorms.

Due to intensive leaching and weathering, the clay fraction of these soils are dominated by kaolinite, halloysites, and/or iron and aluminum oxides (Ssali *et al.*, 1986). Although the low activity clay (LAC) soils are defined as soils with an effective cation exchange capacity (ECEC) of less than 16 meq/100g clay in the sub-soil, observations in West Africa have shown that the majority of the LAC soils have ECEC less than 8 meq/100g clay. These inorganic soil components will contribute little to the soil cation exchange capacity (CEC) (Juo and Adams, 1986).

Table 1 provides information on the fertility status of soils in SAWA. It indicates that the SAWA soils are predominantly sandy, with total sand content ranging from 71% to 99%. The dune soils in the Sahelian zone have very high hydraulic conductivity (150 to 200 cm/day) and are, therefore, characterized by a rapid internal drainage. In the Sudanian zone, there is an increase in clay content, and the formation of crust reduces the internal drainage which often encourages water erosion. The sandy soils are prone to wind erosion. In the Sahel, the beginning of the rainy season is marked by dust storms with violent winds with speed in excess of 100 km/hour. This contributes to wind erosion and crop seedlings are damaged through wind abrasion or buried under sand. These sandy soils have bulk densities ranging from 1.4 to 1.7 g cm^{-3}, corresponding to a porosity of 35 to 43%, and the available soil moisture can be as low as 7%.

One striking feature of the WASA soils is their low levels of organic matter, total nitrogen and ECEC. The main source of nitrogen is organic matter and the level of the latter in these soils explains the low total nitrogen content of these soils. The accumulation of organic matter is highly related to rainfall; thus following the rainfall pattern in the SAWA, increases in soil organic matter follow a north-south gradient.

The soils are also characterized by low CEC which could be attributed to the low organic matter content, the low clay content and the kaolinitic mineralogy of the soils. The effective CEC is more correlated with the organic matter content (OM) of the soil (R = 0.85) than with the clay content (R = 0.39) which demonstrates that most of the colloidal materials in these soils are from organic sources.

Table 1. Range, mean and standard deviation of selected physical and chemical properties of soils in the Sudano-Sahelian zone of West Africa.

Parameter	Range	Mean	Standard deviation
H_20 (2:1 water: soil)	3.85-7.6	6.17	0.66
pH KCI (2:1 KCI: soil)	3.41-7.0	5.05	0.77
Clay (%)	0.7-13	3.9	2.67
Sand (%)	71-99	88	8
Organic matter (%)	0.14-5.07	1.4	1.09
Total nitrogen (mg kg^{-1})	31-226	446	455
Exchangeable bases (Cmol kg^{-1})			
CA	0.15-16.45	2.16	3.01
Mg	0.02-2.16	0.59	0.55
K	0.03-1.13	0.20	0.22
Na	0.01-0.09	0.04	0.01
Exchangeable acidity (Cmol kg^{-1})	0.02-5.6	0.24	0.80
Effective cation exchange capacity (ECEC, Cmol kg^{-1})	0.54-19.2	3.43	3.801
Base saturation (%)	36-99	88	17
Al saturation (%)	0-46	3	8
Total P (,g P kg^{-1})	25-941	136	151
Brayl P (mgP kg^{-1})	1-83	8	14
P adsorption maxima (mgP kg^{-1})	27-406	109	76

Phosphorus deficiency is a major cause of low crop yields in the Sudano-Sahelian zone. The low contents of both total and available P, as shown in Table 1, may be related to several factors, including: (i) parent materials, i.e., granites, sandstones and eolian sands covering the continental terminal, that are low in mineral reserves; (ii) low content of organically-bound P which is a consequence of the low organic matter; and (iii) inadequate nutrient cycling due to removal of grain and biomass from the fields. The P sorption maxima calculated using the Langmuir equation ranged from 27 to 406 mg P kg^{-1} (Manu *et al.*, 1991). These relatively low values show that the soils have a very low capacity to immobilize added phosphorus; consequently, additions of small quantities of P fertilizers will generally satisfy both crops and soils needs.

For the Sahelian zone, Bationo *et al*. (1994) reported that continuous cultivation of fields led to drastic reduction in the organic matter levels but organic amendments can raise the organic matter of soils in these fields to levels close to those found in fallow fields (Fig. 1). In another study, Bationo *et al*. (1991) found that ECEC is more related to organic matter than to clay in the SAWA, indicating that a decrease in organic mat-

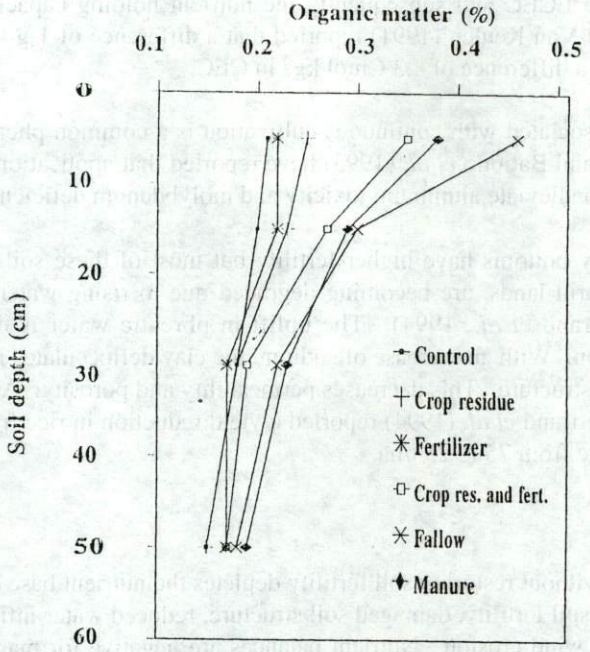

Figure 1. Effect of different management systems on soil organic matter content, Sadore, Niger, 1991 rainy season.
(Source : Bationo *et al.* 1994)

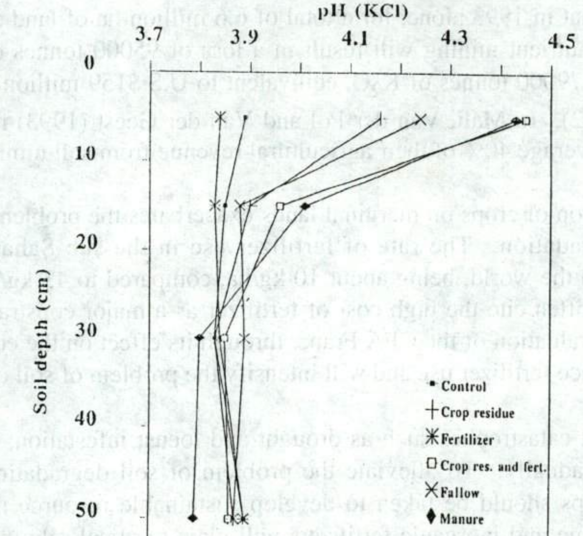

Figure 2. Effect of different management systems on soil Ph at various depths, Sadore, Niger, 1991 rainy season.

(Source : Bationo *et al.* 1994)

ter will decrease the ECEC and subsequently the nutrient holding capacity of soils. Also, De Ridder and Van Keulen (1991) reported that a difference of 1 g kg^{-1} in organic carbon results in a difference of 4.3 Cmol kg^{-1} in CEC.

Soil acidification associated with continuous cultivation is a common phenomenon in the SAWA (Fig. 2) and Bationo *et al.* (1993) have reported that application of organic residue is one way to alleviate aluminum toxicity and molybdenum deficiency.

Soils found in valley bottoms have higher fertility but most of these soils, including those on irrigated farm lands, are becoming degraded due to rising water tables and alkalinization (Bertrand *et al.*, 1994). The uplift in phreatic water is due to poor control over irrigation. With an increase of sodium, the clay deflocculates followed by a breakdown of soil structure. This decreases permeability and porosity. As a result of land degradation, Bertrand *et al.* (1994) reported a yield reduction in rice from 4 to 1.5 t/ha and in sugar cane from 75 to 25 t/ha.

Nutrient mining

Intensive cropping without restoring soil fertility depletes the nutrient base of the soils, resulting in reduced soil fertility, damaged soil structure, reduced water infiltration and increased water and wind erosion. Nutrient balances are negative for many cropping systems in the region with off take greater than input, indicating that farmers are mining their soils (Stoorogel and Smaling, 1990). For example, nutrient mining in Senegal was estimated at 14 kg N, 8 kg P_2O_5 and 14 kg K_2O/ha in 1983, and is projected to increase for 20 kg N, 8 kg P_2O_5 and 21 kg K_2O/ha by the year 2000. Current estimates indicate that in 1993 alone, for a total of 6.6 million ha of land cultivated in Burkina Faso, soil nutrient mining will result in a loss of 95000 tonnes of N, 28000 tonnes of P_2O_5 and 79000 tonnes of K_2O, equivalent to U.S.$159 million of N,P, and K fertilizers (Table 2). In Mali, Van der Pol and Van der Geest (1993) reported that farmers extract on average 40% of their agricultural revenue from soil mining.

In addition, cultivation of crops on marginal lands exacerbates the problem of soil and environmental degradation. The rate of fertilizer use in the sub-Sahara Africa is among the lowest in the world, being about 10 kg/ha, compared to 43 kg/ha for Latin America. Farmers often cite the high cost of fertilizer as a major constraint to adoption. The recent devaluation of the CFA Franc, through its effect on the cost of fertilizer, will further reduce fertilizer use and will intensify the problem of soil degradation.

Unlike rather abrupt catastrophes such as drought and locust infestation, soil fertility decline proceeds gradually. To alleviate the problem of soil degradation and food shortage, urgent steps should be taken to develop sustainable resource management technologies. Organic and inorganic fertilizers will play a critical role in this endeavour as well as other natural resource management approaches.

Table 2. Soil nutrient mining in West Africa (selected countries, 1983).

Country	Area (1000 ha)	Nutrient (Tonnes)		
		N	P_2O_5	K_2O
Benin	2972	-41388 (-14)	-10366 (-3)	-32499 (-11)
Burkina Faso	6691	-95391 (-14)	-27754 (-4)	-78764 (-12)
Ghana	4505	-137140 (-30)	-32313 (-7)	-90474 (-20)
Mali	8015	-61707 (-8)	-17888 (-2)	-66725 (-8)
Niger	985	-176120 (-16)	-55331 (-5)	-146617 (-13)
Nigeria	2813	-1107605 (-34)	-136687 (-10)	-946157 (-29)

Number in parentheses are nutrients mining per hectare.
Source: Bationo *et al*. (1995).

The Role of Livestock in Soil Fertility Management in Semi-Arid West Africa

Animal manure is an integral component of soil fertility management practices in SAWA. Low rural incomes and high cost of fertilizer have prevented the widespread use of inorganic fertilizer. Under this situation, and given the relatively high numbers of livestock in the region, as population pressure increases and fallow cycles are shortened, animal manure becomes one of the principal sources of nutrients for soil fertility maintenance and crop production.

Animal manure increases soil organic matter and nutrient availability and improves CEC and water-holding capacity of soils. It increases yields of crops and forages and, when sufficient quantity is applied on a continuous basis, might permit stable intensified crop production (Mokwunye, 1980; Pichot *et al.*, 1981; Pieri, 1986). Also when used in combination with inorganic fertilizer, especially nitrogen, it serves to reduce the negative effects of fertilizer, particularly acidification, and increases the amount of nutrients other than the quantities supplied by the fertilizer (de Ridder and van Keulen, 1990).

Animal manure application to cropland takes several forms. Farmers can corral their animals overnight on fields during the dry season or they can gather manure from stalls, transport and hand spread it on fields. Corralling returns both manure and urine to soils and results in greater crop yields than when only manure is applied (ILCA, 1993). Corralling also requires no labour for manure handling, storage and spreading. Since approximately 40 to 60% of the N excreted by ruminants is in the form of urine, the potential for nutrient loss is greater when animals are kept in stall (Powell and Williams, 1993).

In addition to livestock owned by farmers, herds of transhumant pastoralists have long been an important source of manure for cropping. Various exchange relationships between farmers and pastoralists exist that allow animals to graze crop residues in return for manure deposition on farmers' fields. However, these practices appear to be declining in many areas due to sedentarization of pastoralists, increasing conflicts between pastoralists and farmers over land rights, and shift of cattle ownership to non-pastoralists.

Despite its vital role in sustaining crop productivity, utilization of manure alone will not permit improvement of soil quality and adequate food production on a long-term basis. This is due to a number of factors. First, there are simply insufficient number of animals to provide the manure needed to sustain cereal yields even at the current low levels (Williams *et al.*, 1995). This problem becomes more pronounced especially in post-drought years. Reconstruction of herds, especially cattle, may take years and consequently cause reductions in manure availability and cropland productivity. Even when sufficient animals are available, feed resources may be inadequate. Depending on rangeland productivity, and taking into consideration availability of crop residues, it will require between 10-40 hectares of dry season grazing land and 3-10 hectares of rangeland for wet season grazing to maintain millet yields on one hectare of cropland in some parts of the Sahel using animal manure (Fernandez-Rivera *et al.*, 1995). Moreover, a total capture of manure nutrients and application to cropland is rarely possible, given the extensive nature of livestock management in SAWA. Given these constraints, it becomes important to devise methods to improve the efficiency of nutrient cycling in SAWA, and to determine the role that other soil amendments can play in the future intensification of agricultural production in SAWA.

Strategies for Soil Fertility Maintenance in SAWA

Lessons learned from long-term soil fertility management experiments

One important lesson that has emerged from long-term soil fertility experiments conducted by the Research Institute for Tropical Agriculture (IRAT) scientists and reported by Pieri (1986, 1989) and Sedogo (1993) is that application of mineral fertilizers is an effective technique for increasing yields in arable farming systems in the Sudanian zone. However, in the long-run, the use of chemical fertilizers alone will lead to decreasing crop yields (Fig. 3). This conclusion is confirmed by results of long-term field trials set up in the Sahelian zone in Niger which show that application of organic materials can counteract the negative effects of chemical fertilizers when used alone (Fig. 4). Not withstanding the yield variation between years due to rainfall and pest and disease incidence, the general trend obtained is that although the addition of chemical fertilizers initially led to higher crop yields compared to addition of crop residues (CR) alone, continuous addition of CR slowly raised yields to levels equal to those of chemical fertilizer plots.

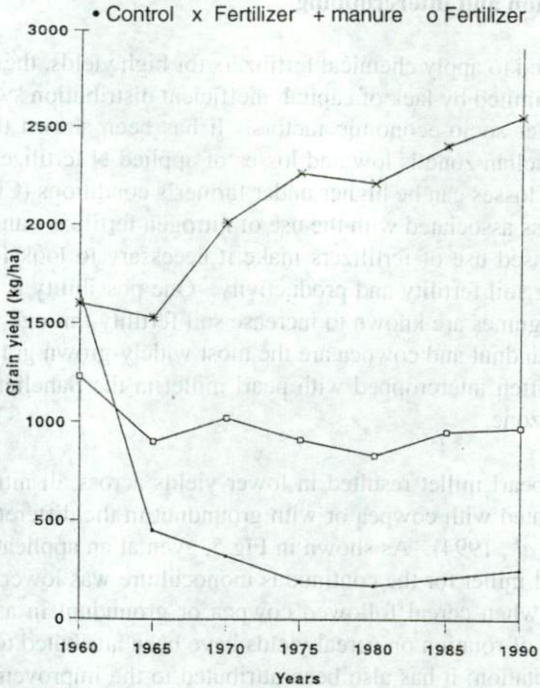

Figure 3. Sorghum grain yield as affected by mineral and organic fertilizers over time. (Source : Sedogo *et al.* 1993)

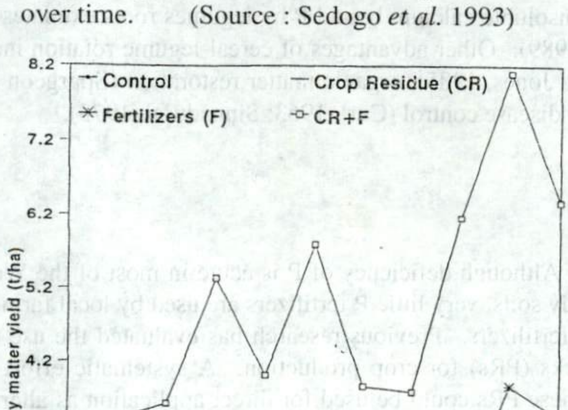

Figure 4. Pearl millet total dry matter yield as affected by different management practices over time. (Source : Bationo *et al.* 1993)

Cropping systems: rotation and intercropping

Despite the recognized need to apply chemical fertilizers for high yields, the use of fertilizers in West Africa is limited by lack of capital, inefficient distribution system, poor communications, and other socio-economic factors. It has been shown that uptake efficiency of N in the Sahelian zone is low and losses of applied N fertilizers of up to 58% are common. These losses can be higher under farmer's conditions (Christianson *et al.*, 1990). The high loss associated with the use of nitrogen fertilizers and the other factors limiting the increased use of fertilizers make it necessary to look for cheaper alternatives for improving soil fertility and productivity. One possibility is rotation of cereals with legumes. Legumes are known to increase soil fertility through their nitrogen-fixing capacity. Groundnut and cowpea are the most widely-grown grain legumes in the SAWA; they are often intercropped with pearl millet in the Sahelian zone and sorghum in the Sudanian zone.

Continuous cropping of pearl millet resulted in lower yields across all nitrogen rates than when millet was rotated with cowpea or with groundnut in the different agroecological zones (Bationo *et al.*, 1994). As shown in Fig 5, even at an application rate of 45 kg N/ha, yield of pearl millet for the continuous monoculture was lower than when nitrogen was applied or when cereal followed cowpea or groundnut in a rotation at Tara. The positive effect of rotation on cereal yields have been attributed to the added N from legumes in the rotation; it has also been attributed to the improvement of soil biological and physical properties (Hooshikawa, 1990) and to the solubilization of occluded P and highly insoluble calcium bound P by legumes roots exudates (Gardner *et al.*, 1981; Ae *et al.*, 1989). Other advantages of cereal-legume rotation include soil conservation (Stracy and Jones, 1985), organic matter restoration (Spurgeon and Grisson, 1985), and pest and disease control (Curl, 1963; Sinnadurai, 1973).

Soil amendments

Phosphate rock (PR): Although deficiency of P is acute in most of the West Africa soils, especially the sandy soils, very little P fertilizers are used by local farmers due to high costs of imported fertilizers. Previous research has evaluated the use of locally available phosphate rocks (PRs) for crop production. A systematic effort has been made to investigate if these PRs could be used for direct application as alternatives to the imported water soluble P fertilizers. The distribution of known deposits of PRs in West Africa is shown in Fig. 6.

The agronomic effectiveness of PR depends on its chemical and mineralogical composition, soil factors, and plant factors. Results of research done by the International Fertilizer Development Center (IFDC) suggest that the agronomic effectiveness of most of the West African PRs is low. Thus, only Matam (Senegal), Tilemsi (Mali) and Tahoua (Niger) PRs were considered sufficiently reactive for direct application. In addition to the above studies, IFDC perfected the "single step" technology for the partial acidulation of phosphate rock; as shown in Table 3, this process increased availability of P in the unreactive PRs (Bationo *et al.*, 1990; Bationo *et al.*, 1991; Mokwunye and Bationo, 1991.

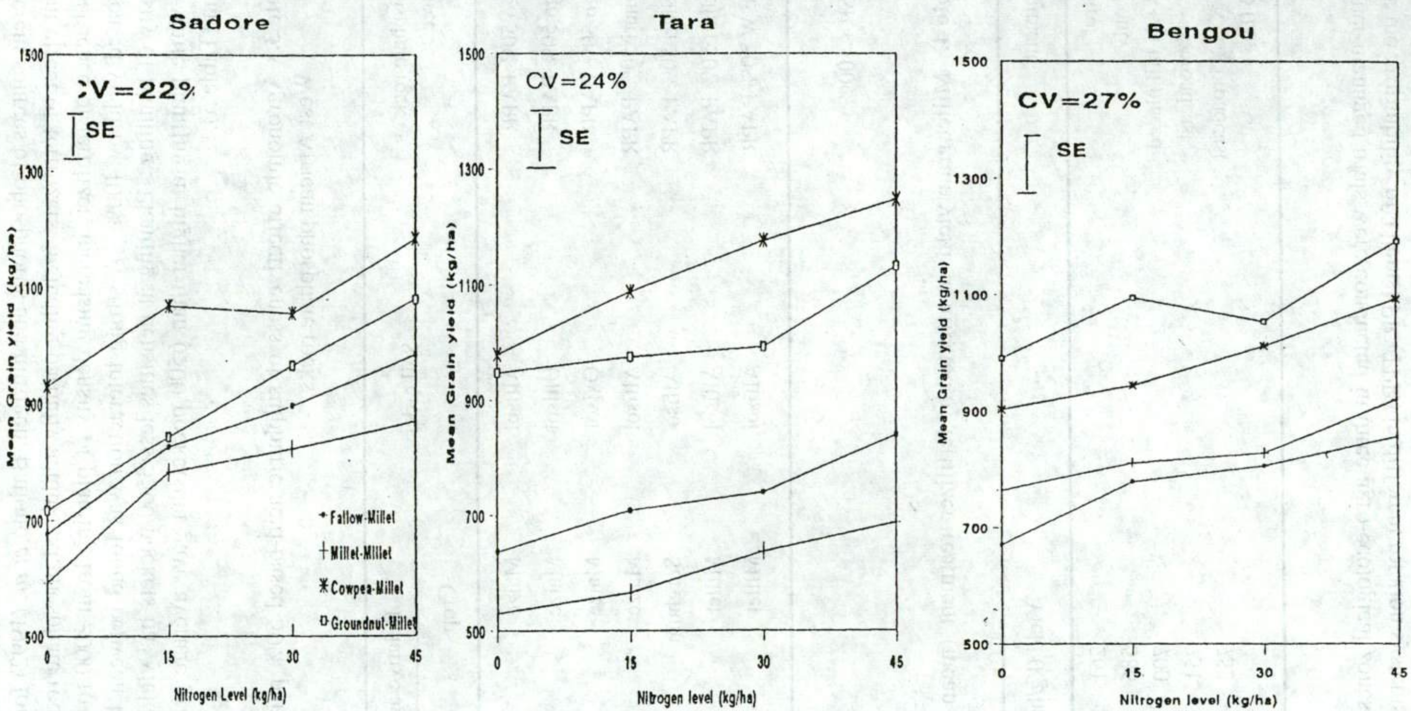

Figure 5:Effect of nitrogen and cropping systems on pearl millet grain yield at Sadore,Tara and bengou,Niger,1989 to 1992 rainy season.

In farmer managed trials conducted in Niger to assess the response of pearl millet to different sources of phosphorus and nitrogen, Bationo *et al.* (1992) found a very significant effect of fertilizers, including partially acidulated phosphate rocks (Table 4). In the absence of fertilizer, increasing density of planting from 2000 to 7000 pockets/ha increased yield by 400%. A strong interaction was found between fertilizer use and density of planting. Planting at densities less 3500 pockets ha^{-1} yielded 317 kg grain ha^{-1} while planting at higher than 6500 pockets/ha gave average grain yield of 977 kg/ha (Table 5).

Table 3. Agronomic effectiveness of sulphuric acid-based 50% partially acidulated West African phosphate rocks.

Phosphate rock source	Soil order	Relative agronomic	
		Crop	effectiveness (%)
Togo 50% PAPR	Alfisol	Maize	90.0
Togo 50% PAPR	Ultisol	Maize	66.7
Togo 50% PAPR	Oxisol	Maize	108.9
Kodjari 50% PAPR	Alfisol	Maize	84.1
Kodjari 50% PAPR	Alfiso	Sorghum	81.3
Kodjari 50% PAPR	Alfisol	Millet	108.9
Parc W 50% PAPR	Alfisol	Millet	93.4

a. SSP + 100%

Table 4. Millet grain yields as affected by fertilizer treatment (mean of 3 years).

Treatment	Yield (kg/ha)
Control	261
SSP only	586
SSP + N hill placed	700
SSP + N broadcast	751
PAPR + N broadcast	752
LSD 0.05	

Farmer managed trials were conducted in three agro-ecological zones of Mali to evaluate the profitability of Tilemsi PR (TPR) in different rotation systems as compared to conventional water-soluble P fertilizers. Results showed that crop yields using TPR were comparable to those of recommended imported fertilizers. The economic evaluation also indicated that direct application of TPR was as profitable as application of imported fertilizers (Bationo *et al.*, 1995).

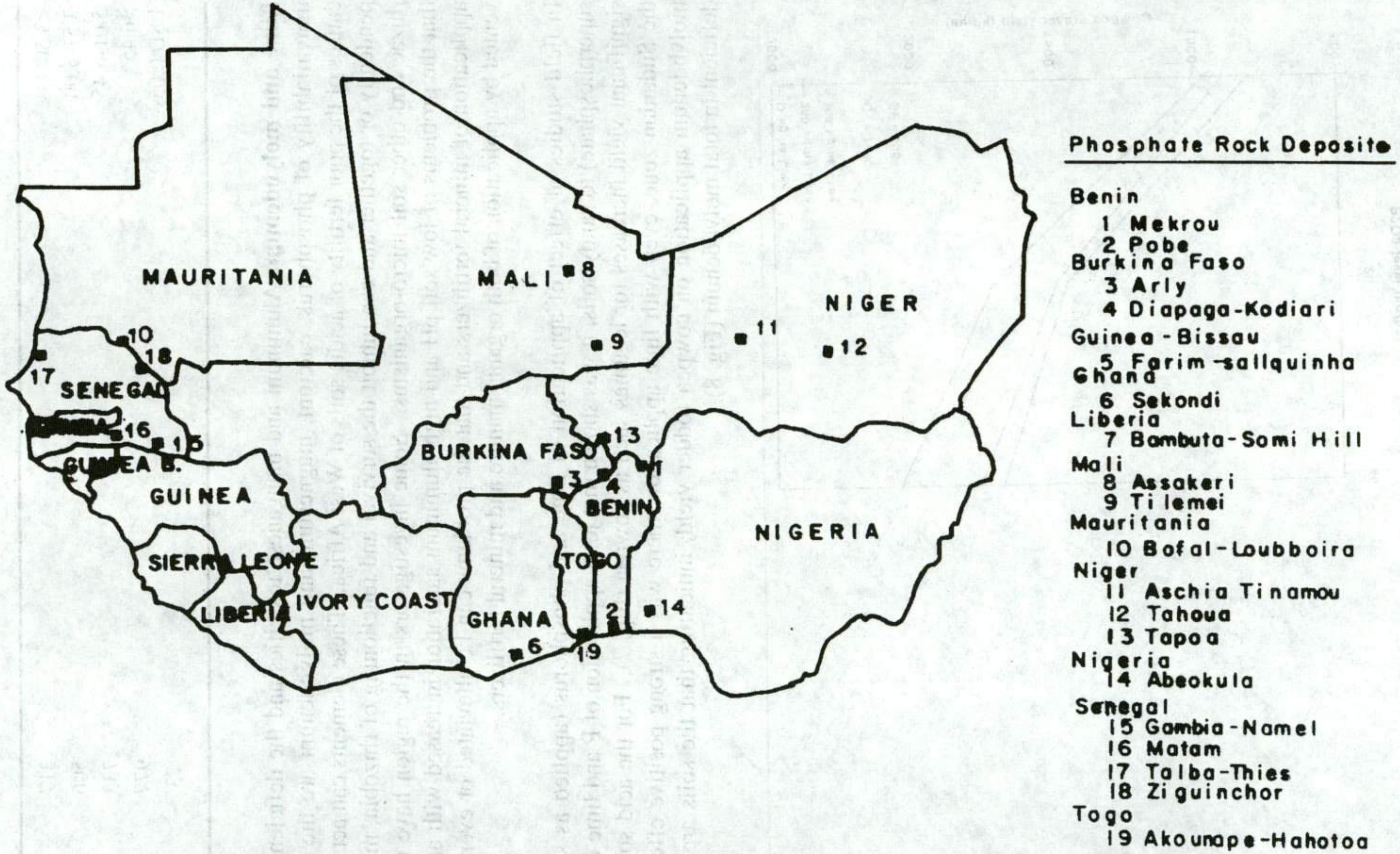

Figure 6. Phosphate Rock deposits in West Africa

Table 5. Millet grain yields in relation to plant density.

Treatment (1,000 pockets/ha)	Yield (kg/ha)
<3.50	317
3.51-5.00	506
5.01-6.45	733
>6.45	977
LSD 0.05	73

Lime and molybdenum: Aluminum and manganese toxicities and the deficiency or unavailability of phosphorus, calcium, magnesium and molybdenum are the main causes of the poor fertility of acidic soils of West Africa. These elements can act independently or together and can inhibit the survival and functioning of rhizobia, mycorrhizae and other soil micro-organisms. Some investigators in the region have noted that the problems of low soil pH and high aluminum saturation increased with annual application of mineral fertilizers and that the problems can be alleviated or even prevented by application of both organic manure and mineral fertilizers.

In field studies of effect of application of lime and phosphorus (applied as single superphosphate) to sandy soils, it was shown that joint application of P and lime led to significant yield increases for legumes such as cowpea (Fig. 7). For the acid soils of the Sudanian zone, even with lime application, there was a strong positive effect of molybdenum application on cowpea fodder yield, indicating that the soils are very deficient in total molybdenum (Fig. 8).

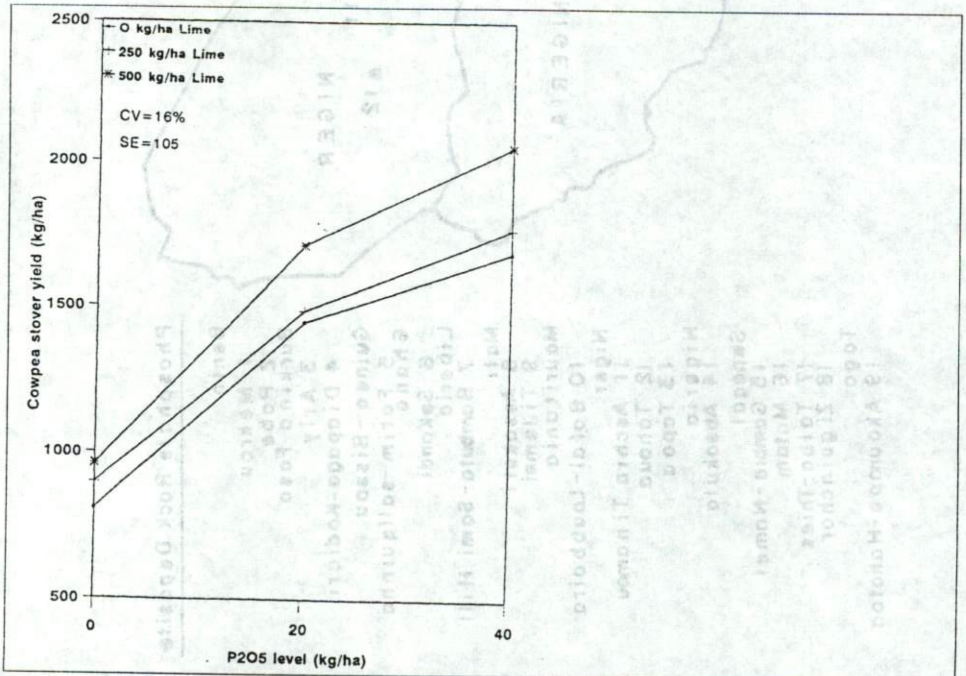

Figure 7. Phosphorus and Lime interaction on Cowpea, Bengou, Niger, 1994

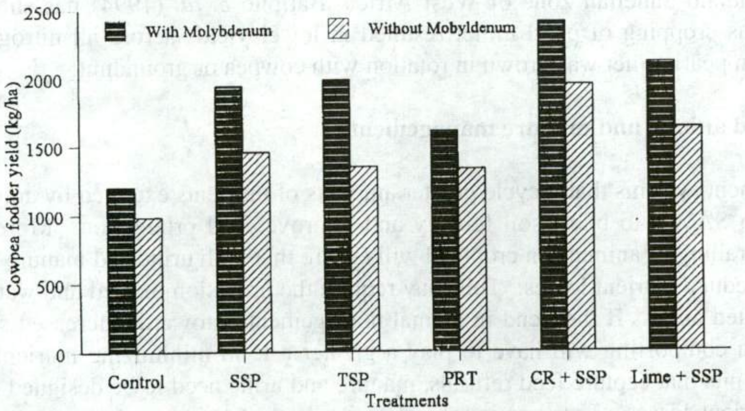

Figure 8. Effect of different sources of phosphorus, crop residue, crop residue, lime and molybdenim on cowpea and groundnut fodder yield, Tara, Niger, 1993.

Improved fallow management

The data for selected countries in West Africa suggest that cropped area as percentage of arable land varies from 10% to 37%. Although most of the present agronomic research has concentrated on cropland, it appears that management of fallow areas should also be given special attention in soil fertility maintenance and biomass production for both humans and animals.

In Northern Nigeria, the introduction of legumes into the traditional fallow systems, to improve the quality of the feed available to ruminants and promote sustainable improvement in subsequent crop yields, has been investigated by scientists of the International Livestock Research Institute. In on-farm trials conducted inside and outside pastoralist owned and managed Stylosanthes fodder banks, Tarawali *et al.* (1992) reported that yields of maize planted in the fodder banks nearly doubled those on natural fallow at each nitrogen level (Fig. 9).

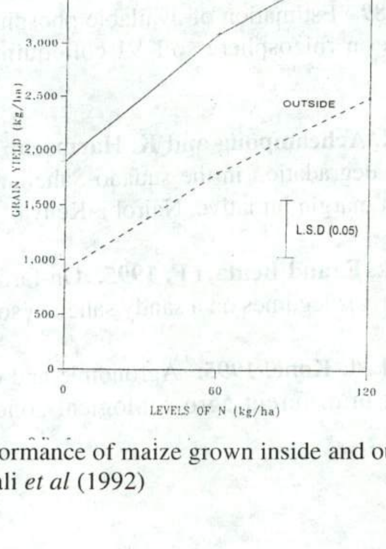

Figure 9. Performance of maize grown inside and outside fodder bank
source : Tarawali *et al* (1992)

In the Sudano-Sahelian zone of West Africa, Bationo *et al.* (1994) has shown that continuous cropping of pearl millet resulted in lower yields across all nitrogen rates than when pearl millet was grown in rotation with cowpea or groundnut.

Improved animal and manure management

Management systems that recycle greater amounts of nutrients excreted by animals are needed in SAWA to boost soil fertility and improve food production. More widespread corralling of animals on cropland will ensure that both urine and manure are captured to reduce nutrient losses. This may require the provision of feed and water close to cultivated areas. If the trend in animal management is towards increased stall feeding, then composting will have to play a greater role in minimizing nutrient losses. Compost pits that capture feed refusals, manure and urine need to be designed to minimize nutrient losses. Low-cost appropriate implements to spread compost over the typically large cultivated areas in SAWA are also needed.
Strategies are additionally required to match manure application and its nutrient release with crop nutrient demands. This requires timely and strategic placement of manure on crop fields. Research is also needed on appropriate combinations of manure and inorganic fertilizers for the different agroclimatic zones of SAWA.

In mixed crop-livestock systems, the issue of competing uses for crop residues as soil amendments and animal feed need to be addressed to ensure efficient utilization of these residues. Research should not only take into account ways to increase crop biomass through efficient use of organic and inorganic fertilizers, but also devise methods to increase the quantity and quality of fodder.

Criteria for selecting legumes for use as windbreaks and as intercrops with cereals need to consider their value as animal feed. There is need to evaluate plants and feeds not only with the view of satisfying animal nutritional demands but in respect of production of animal excreta less susceptible to nutrient losses.

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Livestock Production and Sustainable Agricultural Development in Semi-Arid West Africa

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Abstract

Mixed farming systems, combining crop and livestock activities, hold considerable promise for improved agricultural productivity and environmental conservation in semi-arid West Africa. Increasing population pressure and climatic changes have combined to render long-fallow periods less feasible and effective. Transhumant pastoralism, a productive and historically important pattern of livestock production in the Sahel, is under severe stress due to periodic droughts and extension of cropped lands into range-lands. This paper examines alternative options through which the integration of livestock and crop production could contribute to an intensification of agricultural production and enhance the maintenance of soil fertility in semi-arid West Africa. It reviews several aspects of livestock production focusing on social, economic and technical constraints to pastoral production and to efficient integration of crop and livestock activities. The impact of livestock on the agro-ecosystem is discussed in respect of trampling, spatial redistribution of nutrients and the biological effects of grazing and browsing on the vegetation. Technologies and economic incentives that could improve the contribution of livestock to agricultural production in semi-arid West Africa are identified. The paper demonstrates the necessity of multidisciplinary approach and of active farmer involvement in identifying, designing, and developing appropriate technologies for mixed farming systems in Africa.

Résumé

Les systèmes de production mixe associant l'agriculture et l'élevage s'avèrent très prometteurs pour l'amélioration de la productivité agricole et la conservation de l'environnement en Afrique Occidentale semi-aride. La pression démographique sans cesse croissante et les changements climatiques se sont conjugués pour rendre moins praticables et productifs les longues jachères et le pastoralisme transhumant. Cette communication examine des options de remplacement par lesquelles l'intégration de l'élevage et de la production de cultures pourrait contribuer à une intensification de la production agricole et favoriser le maintien de la fertilité du sol en Afrique Occidentale semi-aride. Elle examine plusieurs aspects de la production animale en insistant sur les contraintes sociales, économiques et techniques à la production pastorale et à l'intégration efficace de la production agricole et animale. Elle analyse l'impact du bétail sur l'agro-écosystème tel que le piétinement, la redistribution spatiale des éléments nutritifs, et les effets biologiques du pâturage et du brout sur la végétation. Elle identifie les technologies et les incitations économiques susceptibles d'améliorer la contribution du bétail à la production agricole en Afrique Occidentale semi-aride. Cette communication démontre la nécessité d'une approche multidisciplinaire et d'une participation active des paysans à l'identification, à la conception et àla mise au point de technologies appropriées pour les systèmes de production mixte en Afrique.

Introduction

Livestock constitute an important component of all agricultural production systems in semi-arid West Africa. Farmers and pastoralists accumulate and use livestock as productive assets to reduce risk and mitigate the effects of drier than average years. For farmers in particular, livestock serve as a cash generator for seasonal requirements of agricultural activity. After a good crop harvest they provide an important investment opportunity for surplus funds, while in poor crop production years they are sold to buy food for household sustenance. Livestock are also kept to complement cropping activities, through the provision of manure and draft power for cultivation and transport. The poor fertility of the sandy soils found in the Sahel has always ensured a role for ruminant livestock in traditional soil fertility management practices.

Approximately 51% of the 37 million tropical livestock units raised in West Africa are found within the seven Sahelian states of Burkina Faso, Chad, Gambia, Mali, Mauritania, Niger and Senegal (Jahnke,1982; ILCA, 1993). The livestock sub-sector's contribution to the agricultural gross domestic product in these countries averaged 35% in 1991, with this share varying from 23% in the Gambia to 83% in Mauritania (USDA, 1993).

Over the last 30 years, the population of all the major domestic animal species found in the region has increased. However, some species experienced more rapid growth than others. Analysis of FAO data indicates that in the seven West African Sahelian countries, the number of cattle, sheep and goats increased by 0.5, 2.2, and 1.7% per year between 1961-63 and 1991-93. Only pigs and poultry, with average annual growth rates of 6.2% grew faster than human population which has been rising at 3.1% per year. This poor growth of livestock inventory has been accompanied by low animal productivity. Production per animal has remained stagnant, or increased only slightly, for most species over the last 30 years. As a result, there has been an increase in imports of milk and meat. Milk imports grew by an average of 6.0% per year between 1971-72 and 1991-92. Currently, the seven Sahelian states import about 4,200 tons of meat annually at a cost of about US$ 7 million.

The poor performance of the livestock sub-sector has also been parallelled by poor growth in the crop sub-sector. Increasing population pressure on land has caused a breakdown of the traditional fallow system used for maintaining soil fertility. The shortening of fallow cycles, without adequate replenishment of soil nutrients, through the use of organic and inorganic inputs, have caused cereal yields to decline over time. To maintain production levels, farmers have had to increase cultivated area and, in so doing, have extended cultivation into more marginal lands. This has led to a decrease in traditional grazing lands and has intensified competition between grazing and cropping systems. With continuing population growth and extension of cultivation into lands of marginal quality, there is an increasing concern about the danger of natural resource degradation in the region.

Another concern relates to food production and economic growth. The dominance of the agricultural sector in the economies of countries in this region suggests that agricultural output needs to increase much more rapidly than population growth in order to ensure higher real incomes, adequate nutrition, and better quality of life for the populace. But this increase in agricultural output must be achieved and sustained without jeopardizing the productive capacity of the natural resource base. Given the characteristics of the existing farming systems in the region, this, amongst other things, calls for appropriate integration of livestock and crop production activities and the development of technologies that offer higher productivity than what currently obtains. Promotion of sustainable systems of agricultural production, in which livestock play a prominent role, is an important part of the agricultural development process in semi-arid West Africa, both because of the relatively high livestock population already existing in the area, and because taking advantage of complementary crop-livestock production interactions represents a least-cost route to agricultural intensification in the region.

This paper addresses the issue of sustainability of livestock and crop production in semi-arid West Africa. Its basic premise is that better integration of livestock and crop production is vital to the sustained productivity of farming systems in the region. It reviews livestock production systems, including the environmental impact of livestock in the zone, and analyses the implications of both complementary and competitive crop-livestock interactions for food production and natural resource management. It identifies strategies for improved livestock production that are consistent with achieving the short-term needs of producers for adequate livelihood, while addressing the long-term considerations of sustainable resource management. It concludes by suggesting ways in which research, technology development, and government policy could be better coordinated to improve livestock production and sustainable agricultural development in the region.

Characteristics of Livestock Production Systems in Semi-Arid West Africa

Pastoralism and mixed crop-livestock farming are two extremes along a continuum of livestock production systems found in semi-arid West Africa. In this section, the main features of these production systems are discussed while the constraints that have inhibited livestock production and adoption of appropriate resource management practices are highlighted.

Pastoral production systems

Pastoralism (extensive rearing of cattle, sheep, goats and camels) has always been a way of life for most of the inhabitants of the drier part of the Sahel where crop production cannot be undertaken but there exist seasonal pastures which livestock can exploit. Irregular availability of pastures and water, as a result of erratic rainfall, makes mobility and flexibility key elements of this system. Pastoral production functions on the basis of periodic movement in search of natural pastures, crop residues and water, but production strategies often change in accordance with perceptions of external conditions which may result in occasional journeys of short duration or seasonal transhumance lasting several months (Swift, 1977; Horowitz, 1983).

During the rainy season, the most productive strategy is to move animals into the drier areas of the semi-arid and arid zones to take advantage of the flush of high quality forage produced by annual grasses. During the dry season, pastoralists attempt to access enough water, crop residues and natural forages to maintain the productive capacity of their herds (Sandford, 1982). Within each season, they take advantage of the patches of pasture that produce more and/or better-quality forage either due to higher soil moisture or fertility (Scoones, 1989).

The migratory nature of this system of production often creates opportunities for mutually beneficial exchange relationships between pastoralists and crop farmers. The exchanges of grain, crop residues, and water for manure have linked crop and livestock production for many years in the Sahel. So also is the practice of livestock entrustment, whereby farmers give their livestock to pastoralists for herding on an annual or seasonal basis (McCown *et al.*, 1979; Tolumin, 1983).

However, the traditional transhumant production system appears to be in a state of transition and is becoming increasingly difficult to sustain. The problem is not simply one of too many animals relative to the available grazing areas. Long periods of below-average rainfall and severe droughts have decimated pastoralists' herds and accelerated the deterioration of rangelands. Movements of herds southward to escape the effects of drought have exposed pastoralists' animals to trypanosomiasis, further reducing the productivity of the surviving herds. Also, past efforts to address the problem of water supplies for pastoralists have often worsened, rather than ameliorated, the problem. Insufficient number of wells and free access to the few available ones have often led to situations where the number of animals congregating around available boreholes exceeded the carrying capacity of the surrounding rangeland, thereby causing rapid deterioration.

Furthermore, in many parts of the region, farmers have taken over the best grazing lands and converted them into cropland, overriding and ignoring the traditional use rights of pastoralists to these rangelands. This process has been accompanied by the increasing cultivation of valley bottoms which has restricted pastoralists movement and prevented them from using these areas as migration routes or pastures during the dry season (Wilson *et al.*, 1983; Turner, 1993). The net effect has been a reduction in total pasture area and seasonal inaccessibility to remaining pastures due to fragmentation caused by cropping and expansion of dry season gardening to low-lying areas. This has forced the pastoralists to remain on deteriorating rangelands and has increased conflicts between pastoralists and farmers.

Nonetheless, it remains true that in the dry parts of the semi-arid zone and in the arid zone, the pastoral system of production represents a rational and profitable system of land use. The challenge to research institutions and development agencies is to improve livestock production and natural resource use in a sustainable manner in the pastoral zone.

The constraints to livestock production in the pastoral zone are diverse in nature. In the past, development approaches were based on insufficient understanding of rangeland ecosystem dynamics and the socioeconomic attributes of pastoral production. Other impediments include: recurrent drought and its effect on pasture availability; breakdown of traditional institutions and systems of managing natural resources; extension of arable farming into traditional grazing lands; land degradation around permanent water points (due to settlement and inadequate distribution of water points); non-existent (or insufficient) delivery of technical inputs and social services; unfavourable terms of trade in exchanging livestock for cereals and manufactured goods, leading to economic marginalization of pastoralists; and increasing incidence of military conflicts in border areas, where pastoralists live, which turn them into refugees, restrict their movements, and prevent them from making a rational use of the ecosystem (Behnke and Kerven, 1994; UNSO, 1994).

Mixed crop-livestock production systems

Mixed crop-livestock production systems are growing in importance in semi-arid West Africa as specialized cropping and pastoral systems are diversifying into livestock and crop production, respectively. Demographic, economic, and ecological factors determine the extent of integration and, indeed, the transition from "pure pastoralism" and "pure cropping" to mixed farming (Boserup, 1965; Ruthenberg, 1980; McIntire *et al.*, 1992).

At low population pressures and when only simple technologies are used for agricultural production, specialized and independent crop and livestock production systems are more attractive than integrated systems, because land is abundant. Labour is the most constraining input at this stage and its cost is high relative to that of land. Soil fertility is maintained through a fallow system, and this is preferred to manure because it requires less labour. Low inelastic demand for agricultural products, due to low population growth and incomes, also ensures low demand for animal power and manure. Herders' mobility is unimpeded because of wide availability of land.

As population pressure rises, demand for arable land increases. Farmers look for alternatives to fallow to maintain soil fertility as extensive techniques of soil fertility maintenance become inadequate to meet crop production demands. Manuring is then initiated, initially through exchange contracts between farmers and pastoralists. As population increases further, cropped land expands and fallows and natural pastures contract. Farmer-herder conflicts increase as access paths to local and regional (transhumance) pastures are obstructed. Extension of land under crops, as evidenced by reduced land availability and shorter fallow periods, increases the incentives for greater crop-livestock integration. At the same time, however, it can produce barriers to integration, if local pasture reductions and resource-related conflict are such that livestock and cropland are separated in space and time. New markets and technologies in some areas have created opportunities to overcome such barriers by providing cash that can be used to purchase substitutes (fertilizers and feed supplements) for local pastures.

In general, the evolution of mixed farming systems in semi-arid West Africa has closely followed the pattern described above. High population growth and the large number of rainfall deficit years, since the late 1960s, have encouraged extensification of arable farming and heightened the competition between grazing and cropping systems. Besides, the cultivation of marginal lands and changes in farming practices (e.g., shorter fallows) have rendered farmers increasingly more vulnerable to climatic risk. It is in light of these developments that mixed crop-livestock systems are seen as offering solutions to the crises of pastoralism and extensive cropping in semi-arid West Africa (Mortimore, 1991).

The crisis of pastoralism centres around the decimation of herds through periodic droughts and the loss of land via alienation and encroachment of farming. The crisis of extensive cropping concerns the shortening of fallow cycles in relation to the restorative needs of the soils and reduction of range to crop land ratio which jeopardizes the system of nutrient transfer (by means of livestock) from range to cropland.

More efficient nutrient management resulting from improvements in manure/crop residue management on fields and improved grazing management of livestock offer the potential for increasing sustainable agricultural productivity. Just as important, livestock represent a source of much needed cash to the farmer for fertilizers which will be required, along with manure, to maintain the productivity of heavily cropped zones.

However, the varying degree of integration of crop-livestock production activities seen across the region indicates that there are still important constraints that inhibit greater integration. Crop-livestock integration may be hindered by lack of capital to purchase animals, or a weak financial position that necessitates frequent sale of livestock. Lack of market access and low output prices may also discourage integration. The lack of adoption of forage legumes and the low demand for animal draft power in most parts of the Sahel have been partly attributed to the absence of price incentives and market conditions under which these technologies have thrived in other parts of sub-Saharan Africa (Pingali *et al.*, 1987; McIntire *et al.*, 1992).

Apart from these economic constraints, there is evidence that as integration progresses beyond certain levels of livestock and cultivation densities, competition increases between crop and livestock for scarce resources, particularly land and labour (Sandford, 1989 and 1990; an Keulen and Breman, 1990; McIntire *et al.*, 1992). The competition for land, for food and feed production, may limit crop-livestock integration. Moreover, integrated systems are labour demanding in terms of crop residue and fodder harvesting, feeding and herding of animals, and manure collection and spreading. Although the point at which labour conflicts will appear in land-scarce and land-abundant zones may differ, the potential for conflict between cropping and livestock for labour is nonetheless real in both systems (Delgado, 1989; McIntire *et al.*, 1992).

There is also evidence which indicates that, irrespective of the extent of integration of crop and livestock production, many of the direct benefits of closer integration are small (Sandford, 1989; McIntire *et al.*, 1992; Williams, *et al.*, 1995). The notable benefits in improved soil quality and fertility, as a result of manuring and the use of animal traction, may not always result in large increases in crop yields due to the low output response of available crop varieties. Besides, it is clear that the overall availability, and the quantities, of manure presently being applied by farmers in the region are inadequate to sustain even the current low yields of cereals on a permanent basis (Fernández-Rivera *et al.*, 1995; Williams *et al.*, 1995). This implies that along with closer crop-livestock interactions, exogenous technical changes involving new seed varieties, fertilizers, and improvement in feed production are needed to raise overall agricultural productivity.

Environmental Impact of Livestock in Semi-Arid West Africa

Grazing animals have often been accused of causing land degradation. The basis for this assertion is as follows. Free access to rangeland in most villages leads to overstocking as each livestock producer tries to keep as many animals as he can, without regard to the long-term consequences of his actions. The high aggregate stocking rate causes pastures to be "overgrazed", and the rangeland deteriorates along a successional sequence away from the climax vegetation. Following this logic, the proposed solutions to overgrazing include destocking, privatization of pastures, and atomization of the production system.

This argument shaped initial external involvement in the pastoral sector and resulted in measures such as sedentarization, water supply schemes, and highly technical range management projects that were undertaken in the early 1960s and up to the 1980s. The failure of these schemes, some of which (e.g., boreholes) even contributed to land degradation, demonstrated that this argument is not well founded.

In recent years, several components of this argument have been challenged. For instance, it has been noted that access to many pastures is indeed governed by common property regimes in which groups of resource users regulate resource use by members of the groups. The ecology of African rangelands and the processes that mediate the influence of livestock on the environment are also better understood (Behnke *et al.*, 1993; Hiernaux, 1993; Dodd, 1994).

The impact of grazing livestock on the soil and vegetation depends upon a complex set of interactions involving selective plant defoliation, soil trampling and manure deposition. The importance of each of these processes depends on the intensity, frequency and timing of grazing, soil texture, terrain slope, and duration of the rainy season (Hiernaux, 1993).

In northern Sahel, pastures are dominated by annual species that are relatively unaffected by grazing pressure because of the shortness of their growth cycle (Breman and Cissé, 1977). The state of the pasture in this zone is much more dependent upon episodic climatic events than the stocking rate. In addition, lack of permanent water points usually prevents these pastures from being overgrazed. In these "non-equilibria" pastures, it is most important that pastoralists maintain access, or use rights, to a variety of pasture and water resources and the right to move between those resources.

The herbaceous plants found in the southern part of the Sahel have a longer growing cycle and are, therefore, more sensitive to grazing (Oesterheld and McNaughton, 1991). Because they grow over a longer period, they are exposed to continuous grazing by sedentary livestock, especially during the cropping season. This promotes changes in plant species composition and severe degradation of the vegetation, with less palatable plants becoming dominant.

Moreover, fallows constitute most of the pastures in the southern Sahel. The effect of grazing livestock comes only after the severe impacts of clearing and repetitive cropping on vegetation and soil. When clearing land for cultivation, only a few useful trees are usually left in the fields. Continuous cropping also degrades soil structure and

depletes soil nutrients, while frequent weeding affects the soil seed stock.
More studies are obviously needed to gain a better understanding of the cropping and grazing processes that encourage land degradation. This would help to identify sustainable crop and livestock management practices for the different zones in the region.

Strategies for Improving Livestock Production in Semi-Arid West Africa

Pastoral production systems

Past efforts aimed at improving pastoral production systems have historically evolved through two phases. First, there were sector-specific, technically-oriented range management projects, water supply, animal breeding and veterinary service schemes that were undertaken from the early 1960s to the mid 1980s. Most of these schemes did not improve pastoral production or livelihood because of inadequate consideration of the social and economic motivations of pastoralists, their non-inclusion in the decision-making process, and lack of understanding of rangeland ecosystem dynamics (UNSO, 1994). Second, since the late 1980s, there has been a move towards greater involvement of pastoralists in the planning and implementation of programmes affecting their livelihoods (World Bank, 1994). These past experiences have provided valuable lessons and a justification for new strategies for pastoral development.

New approaches need to emphasize natural resource management, support for local institutions that govern resource use, greater devolution of decision-making to pastoralists, and appropriate government policy for the supply of inputs and social services.

Recent research on rangeland ecology suggests that the natural environments used by pastoralists are generally robust and resilient (Hiernaux, 1993). There is also evidence that conventional range management techniques may be inappropriate for many rangelands in sub-Saharan Africa (Dodd, 1994). In this situation, a viable option involves adequate protection and appropriate management of the dry season pastures that are at the heart of the pastoral production system.

The spatial and temporal variability that exists in dry areas makes mobility and flexibility important aspects of the pastoral production system. Common property or access to large land area is desirable in this case, since it can reduce production losses in poor rainfall years. This calls for the strengthening of local resource-use institutions or, where these institutions have proved inadequate, the establishment of new ones to negotiate and guarantee the rights of pastoralists to range and water resources.

In consonance with economy-wide reforms taking place in much of Africa, two types of policy reforms are needed for pastoral development: those supporting greater involvement and devolution of power to pastoralists, and those that cover activities and services which remain the strategic responsibility of national governments (e.g., maintenance and storage of food reserves, provision of market outlets in remote areas, drought contingency preparedness, insurance schemes, and protection of transhumance corridors). Devolution of power must be performed cognizant of the spatial and temporal aspects of existing systems of formal and informal usufruct rights. The short history of natural resource management devolution in the Sahel has, more often than not, resulted in resource appropriation by one group and system of production, resulting in a reduced potential for crop-livestock integration. The formation of pastoral organizations, while a necessary step to foster greater local responsibility over resource management, is insufficient without the granting of enforceable usufruct rights.

Mixed crop-livestock production systems

In areas where further intensification of crop and livestock production is feasible and desirable, the evolution and development of mixed farming can be improved through a coordinated approach involving technical, economic and policy interventions.

The initial challenge to research and technology development is to identify the predominant production systems and target the key research issues that are likely to have the maximum positive impact on livestock and crop production.

Farming systems research methods, utilizing rural appraisal techniques and whole-farm models, can be used to identify the stage of evolution of crop-livestock integration, the feasibility of further integration, and the physical, social and economic constraints to sustainable increases in the productivity of the mixed farming system. Furthermore, classification of livestock-crop producers into homogenous units with similar constraints and characteristics, using quantitative techniques, such as, cluster analysis can be particularly useful in identifying important issues that component biological research should address (Monicat *et al.*, 1992; Williams, 1994).

While common constraints across the region include inadequate feed resources, declining soil fertility, lack of access to inputs, inadequate market facilities, and poor rural infrastructure, the relative importance of these constraints vary greatly among zones. Similarly, different research strategies exist to tackle these constraints. The strategy chosen must reflect the current degree of crop-livestock integration. For example, strategies to improve manure utilization will be dictated by the stage of evolution of the farming system. In integrated systems, where manure use is already significant, the problem will be how to improve the efficiency of nutrient cycling, while in systems where crop and livestock production are independent, and manure is obtained through contracts between farmers and pastoralists, the issues might be how best to ensure effective contracts and efficient nutrient cycling.

An increase in feed production and quality, and diet supplementation to overcome seasonal nutritional constraints are needed to improve livestock production in semi-arid West Africa. To this end, the integration of grain and forage legumes and browse trees can serve an important role in sustaining the productivity of crops and livestock in the zone. Forages which fix atmospheric nitrogen can be more effective than native grasses in restoring soil fertility on fallows, thereby reducing fallow period requirements. On cropped fields, forage legumes can suppress weed growth, improve soil fertility and moisture conservation, and provide animal feed. Wind breaks using browses and perennial grasses can control soil erosion; enhance soil productivity; and provide food, fodder, and wood. However, in most areas, land allocation to forage is hindered by lack of exclusive use rights and land tenure insecurity. Also, when forage legumes are intercropped with cereals, there may be initial trade-offs in grain and feed output. Forage legume-cereal intercropping often increases the quantity and feeding value of crop residues, but decreases the yield of the companion cereal crop (Mohamed-

Saleem, 1985; Kouamé *et al.*, 1993). However, grain yields are improved when cereals are rotated with short-term fallows of forage legumes (Mohamed-Saleem and Otsyina, 1986). In areas with poor market access, increased labour requirements of forage production, in relation to the gains from feeding forage to livestock, may also impede forage production by smallholders. In sum, profitable management techniques are still required, if forage legumes are to be widely adopted in the region. Adoptable legumes must be easy to cultivate, regenerate readily, and not harmful to the accompanying or succeeding crop.

Grain legumes (cowpeas, groundnuts, etc.) are already an integral part of many mixed-farming systems in the region. Their residues are valuable diet supplements for livestock and income sources for rural households. Many grain legumes, however, shed their leaves at grain maturity which greatly reduces their feeding value. Dual purpose grain-forage legumes that retain their leaves are needed to provide both food and feed.

Research is clearly needed on methods to reduce the competition between animals, soil conservation, and farm households for crop residues. Long-term trials with farmers' active involvement are needed to assess the feasibility and impact of various crop residue use strategies on animal and soil productivity.

Strategies are also required that synchronize manure application and its release with plant nutrient demands. The application of organic amendments to soil, such that their decomposition and nutrient release coincide with crop nutrient demands, can greatly increase the efficiency of nutrient cycling in low-input farming systems (Swift *et al.*, 1989). Timely and strategic placement of manure through improved manure handling, storage, and hand spreading techniques can enhance nutrient cycling in these mixed farming systems.

Although the transfer of nutrients from uncultivated to cropped lands by animals is a critical component of nutrient cycling in mixed farming systems, the transfer mechanisms are poorly understood. The capacity of rangelands to support livestock and nutrient harvesting needs to be assessed at various rangeland:cropland ratios (Turner, 1995). Sustainable mixed farming demands information on nutrient acquisition and use by animals, including grazing behaviour, herding practices, and the effects of grazing and browsing on rangeland vegetation, and on animal and soil productivity.

The proper use of inorganic fertilizers, insecticides and other pesticides, and concentrate feeds will be crucial in increasing crop and livestock productivity in the region. However, these purchased inputs continue to be costly and unavailable to most farmers. Appropriate policies are needed to ensure adequate supply and timely access to these inputs at reasonable cost. Extension education on fertilizer and pesticide use, and the provision of fertilizer-responsive crop varieties are additional measures needed to encourage the adoption of these inputs.

The range of cultural, technical, and socioeconomic issues involved in crop-livestock interactions necessitate an interdisciplinary approach to ensure that the technical interventions are ecologically sound and socially acceptable to farmers. The appropriateness and adoption of improved livestock, crop and soil management practices by farmers will depend on their profitability. Therefore, farmers need to be fully involved in all stages of technology development and assessment.

Conclusions

For the foreseeable future, livestock production will continue to be of immense economic and social importance in semi-arid West Africa. New approaches are needed, however, to foster livestock production and promote better integration of crop and livestock activities in the region. Past experience has shown that sector-specific solutions that ignore cross-sectoral linkages and synergies will fail. Technical interventions must simultaneously improve livestock and crop productivity. But apart from developing new technologies, appropriate policies are needed to provide economic incentives for better crop-livestock integration and natural resource use throughout the region.

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Gestion de la Fertilité des Sols et Développement des Technologies Appropriées pour une Agriculture Durable au Nord-Cameroun

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Résumé

Les sols des zones Soudano-Sahélienne et Sahélienne du Nord Cameroun sont peu fertiles. Les études menées pour une amélioration du niveau de fertilité et le développement des techniques appropriées ont porté sur:

- les méthodes de préparation du sol: labour simple, travail au chisel et non labour combinées au billonnage simple et cloisonné sous maïs et sorgho. Les résultats mettent en évidence un effet supérieur significatif du labour simple par rapport au travail au chisel et au non labour. Le billonnage simple et le billonnage cloisonné sont significativement supérieurs au semis à plat.
- la fertilisation minérale par la détermination des doses optimales d'engrais pour les différents systèmes de cultures: sorgho continu, sorgho après cotonnier, sorgho après arachide ou niébé, sorgho associé à l'arachide ou au niébé. Les résultats montrent que l'obtention d'un rendement optimum d'une culture continue de sorgho nécessite une dose élevée d'engrais comparativement au sorgho après le cotonnier, l'arachide, le niébé ou en association. On n'observe aucune modification significative du bilan minéral sous culture continue avec utilisation d'engrais.
- l'utilisation des légumineuses fourragères pour protéger le sol contre le ruissellement et l'érosion et en outre enrichir le sol en azote: *Mucuna Pruriens* et *Canavalia ensiformis* accumulent le maximum de biomasse entraînant une diminution de la température du sol. *Cajanus cajan* présente l'avantage d'une biomasse plus persistante en saison sèche.

Abstract

In the Sudan-Sahelian and Sahelian zones of Northern Cameroon soils are characterized by low fertility. Studies conducted to improve fertility and to develop appropriate technologies encompass:

Soil preparation methods: conventional tillage, tillage with chisel and tillage zero are combined with simple and tied ridging under maize and sorghum. Results show that conventional tillage is significantly superior to tillage with chisel or tillage zero, with tied ridging and simple ridging being significantly superior to flat tillage.

The identification of optimum fertilizer rates for the various cropping systems: continuous sorghum, sorghum after cotton, sorghum after groundnut or cowpea, sorghum intercropped with groundnut or cowpea. The results show that optimum yield of continuous sorghum crop requires a high fertilizer rate compared to sorghum after cotton, groundnut, cowpea or intercroping sorghum. There are no significant modifications of the soil chemical properties under continuous cropping with the use of fertilizers.
The use of fodder legumes to protect soil against run-off and erosion with an additional effect of soil enrichment with nitrogen: results indicate that *Mucuna pruriens* and *canavalia ensiformis* accumulate most biomass resulting in a reduction of soil temperature. The advantage of Cajanus Cajan is to have a more persistent biomass during the dry season.

Les contraintes à la production

Les principales contraintes à la production des cultures vivrières dans les provinces Nord et Extrême-Nord du Cameroun sont:

Le climat: caractérisé par une pluviométrie insuffisante et mal répartie.

La pauvreté physique et chimique des sols. Des jachères de plus en plus courtes alternées à de longues périodes de cultures sans apport d'engrais entraînent des diminutions de la fertilité des sols. La faible capacité d'infiltration de certains de ces sols les rend susceptibles à l'érosion.

Les insectes, les maladies et autres pestes: spécifiques à chaque culture.

Les techniques culturales mal appropriées: les associations culturales sont les systèmes de cultures les plus pratiqués, mais leur non-amélioration entraîne des rendements faibles au niveau des paysans.

Le manque de variétés améliorées à hauts rendements et résistantes aux maladies, insectes et autres pestes.

Les solutions envisagées

L'objectif de la recherche-développement consiste à lever certaines de ces contraintes. Parmi celles-ci nous nous limitons ici aux aspects suivants:

1 - Les méthodes de préparation du sol.
2 - La fertilisation.
3 - Les rotations des cultures.
4 - Les légumineuses de couverture.

Les Méthodes de Préparation du Sol

La technique des billons cloisonnés a été évaluée sur le niébé dans le but de limiter le ruissellement et l'érosion afin d'améliorer l'infiltration de l'eau dans le sol. Le semis du niébé se fait à plat, 3 semaines après on procède au billonnage simple et au billonnage cloisonné tous les 4-5m (Endondo, 1990; Endondo et Detongnon 1992). Le dispositif expérimental est une combinaison factorielle de 3 modes de préparation du sol-plat, billons simples, billons cloisonnés) et 2 cultivars de niébé (Vya et TVX 3236) en blocs complets randomisés en 5 repétitions.

Les résultats de 3 années d'expérimentation (tableau 1) indiquent que les billons cloisonnés provoquent une augmentation de rendement de 461 kg/ha, soit 53% par rapport au semis à plat. Les billons simples quant à eux entrainent une augmentation de rendement de 94 kg/ha, soit 10.9% par rapport au semis à plat pour la variété Vya, à port rampant et photosensible. Les augmentations sont de 44 % et 24 % sur TVX3236, à port érigé et photo insensible, pour les billons cloisonnés et pour les billons simples respectivement. Cet effet positif des billons cloisonnés est cependant atténué pendant les années de bonne pluviométrie, où on assiste à une stagnation d'eau au niveau des sillons, ce qui entraine si le phénomène se prolonge une asphyxie racinaire et par conséquent une mauvaise croissance du niébé.

Tableau 1. Effet du billonnage cloisonné sur le rendement du niébé

Traitement		Rendement moyen sur 3 ans (1985,86,87) (kg/ha)
VYA	plat	859
	billons simples	953
	billons cloisonnés	1320
TVX 3236	plat	843
	billons simples	1046
	billons cloisonnés	1214

Ont été également évalués, le labour simple, le travail au chisel et non-travail du sol. Chacune de ces méthodes est combinée au billonnage simple et au billonnage cloisonné sous maïs et sorgho. Le labour simple consiste au labour à la charrue à disques, suivi d'un hersage croisé. Le non-labour consiste à l'utilisation d'herbicides de contact (BastaA 4 l/ha) et d'un herbicide de pré-émergence (Primextra 4 l/ha) suivi d'un buttage un mois plus tard après application de l'urée.

Les résultats présentés dans le tableau 2 montrent que pour le maïs, le labour simple est significativement supérieur au chisel et au non-labour. Il n'y a pas de différence significative entre le travail au chisel et le non-labour. Les traitements avec les billons cloisonnés sont significativement supérieurs à ceux avec les billons simples. Pour le sorgho, les résultats sont similaires à l'exception du non-travail du sol qui a donné un rendement supérieur au chisel.

Tableau 2. Effet du mode de préparation du sol et du billonnage sur le rendement grain du maïs et du sorgho au Nord Cameroun. Djalingo 1991 et 1992.

Mode	Billon	Maïs CMS-8806	Maïs TZPB-SR	Sorgho CS 95	Sorgho Damougar
				(t/ha)	
labour	cloisonné	6.60	7.06	3.29	2.67
labour	simple	5.96	6.12	2.13	2.05
chisel	cloisonné	5.20	6.40	1.37	1.48
chisel	simple	4.24	5.26	1.09	1.23
non labour	cloisonné	5.28	6.20	1.68	1.94
non labour	simple	3.80	5.0	1.08	1.30
Moyenne		5.18	6.01	1.77	1.78

maïs : cv=7%, ppds=0.48 t/ha ; sorgho : cv=13% ppds=0.86 t/ha

La fertilisation

La détermination de la dose optimum d'engrais chimiques pour les différents systèmes de culture que sont : sorgho continu, sorgho après cotonnier, sorgho après arachide et/ou niébé, sorgho associé à l'arachide et/ou au niébé a été réalisée. Le dispositif expérimental est une combinaison factorielle de 7 doses d'engrais et de 4 systèmes de cultures en blocs complets randomisés repétés 4 fois. Il s'en suit que l'obtention d'un rendement optimum sous culture continue de sorgho exige une forte dose d'engrais (40kgN + 20kg P_2O_5 + 20kgK_2O/ha), comparé à 20kg de N, P_2O_5 et K_2O si le sorgho est semé après le cotonnier, ou à 20N, 20P_2O_5 après l'arachide ou associé à l'arachide, (tableau 3). L'arrière effet marquant de la fumure coton ou arachide explique les doses plus faibles nécessaires pour l'obtention d'un rendement optimum de sorgho semé après cotonnier, arachide ou associé à l'arachide.

L'étude de la drèche de brasserie et du tourteau de coton comme source supplémentaire d'éléments fertilisants sur maïs et sorgho complétés par les engrais chimiques (90N - 40 P_20_5 -40K_2O kg/ha sur maïs et 45N - 40P_20_5 - 40K_2O kg/ha sur sorgho) a montré que l'utilisation de l'engrais minéral seul doublait les rendements. L'utilisation combinée de l'engrais minéral et de la drèche ou du tourteau augmentait en plus le rendement de 10 à 50 % suivant la quantité utilisée, (Tableau 4). Ceci montre un effet bénéfique de la drèche sur l'efficience des engrais utilisés.

Tableau 3. Effet des systèmes de cultures et du niveau de fertilisation sur le rendement du sorgho à l'Extrême-Nord du Cameroun, 1990 - 1992

Fertilisation	Sorgho continu	Sorgho après coton	Sorgho après arach.	Sorgho + Arach. en assoc.
	(kg/ha)			
0 - 0 - 0	769	1250	1606	990 + 566
0 - 20 - 20	1548	1991	1955	1091 + 532
20 - 20 - 20	1938	2401	2282	1210 + 470
40 - 20 - 20	2200	1618	1950	1158 + 486
60 - 20 - 20	1826	1590	1804	1050 + 473
20 - 0 - 0	1088	1639	1505	1045 + 506
20 - 20 - 20	1703	2017	2398	1417 + 470
Moyenne	1582	1787	1929	1137 + 500

SE système = 73 ; fertilisation = 107 ; S x F = 193

Tableau 4. Effet du tourteau de coton et de la drèche sur le rendement grain du maïs (TZPB) au Nord-Cameroun, 1990 - 1992.

Traitement	Djalingo		Sangueré	
	Rdmt (t/ha)	RGR %	Rdmt (t/ha)	RGR %
témoin (aucun apport)	1.73	49	1.04	39
engrais	3.50	100	2.71	100
engr. + 200kg drèche/ha	4.18	119	3.43	127
engr. + 400kg drèche/ha	4.62	132	5.04	186
engr. + 800kg drèche/ha	5.13	147	5.50	203
engr. + 200kg tourt./ha	4.54	130	3.29	121
engr. + 400kg tourt./ha	5.26	150	516	190
engr. + 800kg tourt./ha	5.57	159	6.34	234

Djalingo : cv = 6% ppds (0.05) = 0.38 t/ha
Sanguéré : cv = 7.5% ppds (0.05) = 0.43 t/ha
RGR = rendement grain relatif en %
engr. = engrais

Rotation culturale

Des études ont été conduites afin d'améliorer l'effet des différentes rotations sur les besoins en éléments fertilisants du maïs semé sur une rotation d'un an avec les légumineuses à graines (arachide, pois d'engole, niébé) et *Crotalaria caricea* dans un alfisol représentatif de la savane de basse altitude. Les pratiques culturales sont celles des paysans : les résidus des récoltes sont enlevés avant le semi du maïs. Quatre niveaux d'azote sont testés avec le maïs, (0, 45, 90, 135 kg/ha avec l'urée comme source d'azote et 60 P_2O_5 + 60 K_20 + 18 S kg/ha.). Le dispositif expérimental est un split-plot avec comme facteur principal le précédent cultural et comme facteur secondaire le taux d'azote. Les résultats sont présentés dans le tableau 5.

On observe une réponse hautement significative du maïs à l'azote. L'amplitude de la réponse varie avec le précédent cultural. A la dose la plus élevée d'azote un surplus de rendement de 3.52 t/ha (49%) a été obtenu. Le meilleur précédent cultural a été le *Crotalaria*, tandis que le moins favorable était le maïs. Tous les traitements légumineuse-maïs ont été meilleurs par rapport au maïs continu. Sans azote, le traitement *Crotalaria*-maïs a donné un rendement de 1.47 t/ha (62%) de plus que le traitement maïs-maïs.

Tableau 5. Réponse du maïs à la fertilisation azotée sous différents précédents culturaux au Nord Cameroun. 1991 - 1992.

N kg/ha	**Précédent cultural**					
	Crotalaria	**Pois** d'angole	Niébé	Arach.	Maïs	Moy.
0	3.83	3.55	3.71	3.11	2.36	3.31
45	5.52	4.80	4.67	4.67	4.10	4.86
90	6.70	6.07	6.07	6.07	5.23	6.10
135	7.25	6.75	6.39	6.39	5.88	6.64

cv = 10% ppds (N) = 0.160 t/ha ppds (p.cult.) = 0.144 t/ha

Une étude similaire a été menée sur maïs et sur sorgho avec comme précédents culturaux : niébé, arachide, pois d'angole, soja, *Crotalaria*, cotonnier et céréales. La dose d'engrais est 130 N + 60 P_20_5 + 60 K_20 + 18 S kg/ha. La rotation cotonier-céréales pratiquée par les paysans sert de témoin. Le dispositif expérimental étant une combinaison factorielle de 7 précédents culturaux (niébé, arachide, coton, pois d'angole, céréale, *Crotalaria*) et des deux céréales en blocs complets randomisés. Les résultats présentés au tableau 6 indiquent un bon comportement du maïs et du sorgho après les différentes légumineuses comparativement au cotonnier, ce qui traduit par des rendements plus élevés. Il y a des différences hautement significatives entre les précédents culturaux en ce qui concerne les rendements grains. Les rendements les plus élevés du maïs et du sorgho sont obtenus après *Crotalaria* (jachère améliorée). Les plus bas l'étant après une céréale. Il n'y a pas d'interaction significative entre les deux cultures tests (maïs, sorgho) et le précédent cultural, ce qui indique que les deux cultures ont une réponse similaire au précédent cultural. Les meilleurs précédents culturaux pour le maïs et le sorgho sont le *Crotalaria* et le niébé.

Tableau 6. Effet de différents précédents culturaux sur le rendement grain du maïs et du sorgho au Nord Cameroun. 1992 - 1993.

	Précédent cultural			
	Maïs	Augment.	Sorgho	Augment.
	(t/ha)			
Niébé	6.38	0.75	1.84	0.56
Arachide	5.89	0.26	1.53	0.25
Coton (témoin)	5.63	-	1.28	-
Pois d'angole	5.87	0.24	1.61	0.33
Soja	4.78	0.15	1.28	0
Céréale (maïs/sorgho)	4.48	(-1.15)	1.05	(-0.23)
Crotalaria	6.69	1.06	2.81	1.53

F = H.S CV = 12%

Les légumineuses de couverture

Les effets bénéfiques que procurent les légumineuses fourragères sont entre autres : la production abondante de mulch qui protège le sol contre l'érosion et le ruissellement et favorise l'infiltration de l'eau dans le sol, le recyclage des éléments nutritifs, la production de fourrage de bonne qualité, la suppression des adventices (Endondon, 1994). Il est nécessaire d'identifier les légumineuses qui couvrent rapidement le sol et au mieux celles dont la couverture végétale persiste pendant la saison sèche.

Dans cette optique, plusieurs légumineuses (*Mucuna pruriens, Canavalia ensiformis, Cajanus cajan, Stylosanthes hamata, Calopogonium mucunoides*) ont été semées sur alfisols ferrugineux en trois répétitions. Les distances entre les lignes étant de 1m pour toutes les espèces. La couverture du sol a été estimée par la méthode de la corde (Sarrantonio, 1990). Les résultats d'une première expérimentation montre que Mucuna couvre rapidement le sol et procure une bonne couverture végétale pendant la saison sèche. *Canavalia ensiformis* couvre moins rapidement le sol mais accumule le plus de biomasse sur une longue période. *Cajanus cajan* a une croissance lente au début, mais continue à croître pendant la saison sèche sans toutefois couvrir le sol complètement.

Une deuxième étude avec le maïs et le sorgho en association avec les légumineuses fourragères (tableau 7) montre qu'il n'y a aucune différence significative entre les traitements au niveau des rendements maïs et sorgho. La diminution de rendement par rapport à la parcelle pure est de 4% pour le maïs et 9% pour le sorgho. Récoltées 45 jours après la récolte du maïs, la biomasse produite par *Calopogonium* est de 3 t/ha, pour *Stylosanthes* 4.3 t/ha, pour *Canavalia* 8.1 t/ha et pour *Cajanus cajan* 8,75 t/ha. En Novembre déjà les feuilles de *Calopogonium* et *Stylosanthes* avaient séché alors que celles de *Canavalia* et de *Cajanus* restaient vertes. Ce qui présume à une meilleure utilisation des reserves hydriques du sol. Ces deux dernières légumineuses présentent l'avantage de conserver leurs feuilles pendant la saison sèche, celles-ci peuvent servir de fourrage aux animaux.

Tableau 7. Effet de l'association avec les légumineuses fourragères sur le rendement grain du maïs et du sorgho au Nord Cameroun. 1991 - 1992.

Maïs ou sorgho associé avec	Maïs		Sorgho	
	Rdt (t/ha)	RGR %	Rdt (t/ha)	RGR %
Calopogonium	5.33	95	1.79	90
Stylosanthes	5.50	98	1.85	93
Canavalia	5.27	94	1.69	85
Cajanus	5.29	94	1.87	94
parcelle pure	5.63	100	2.01	100
Moyenne	5.40		1.84	

Maïs F (tr) = N.S. C.V = 6% Sorgho F(tr) = N.S. C.V. = 17%

Conclusion

Le développement durable de l'agriculture Camerounaise en général et des zones septentrionales en particulier nécessite l'introduction et l'utilisation des légumineuses dans les systèmes de culture. Plusieurs légumineuses y sont adaptées. La combinaison de ces légumineuses aux techniques de cultures appropriées présente des aspects positifs au niveau du maintien et de la restauration de la fertilité des sols, ce qui se traduit par une production soutenue et élevée et une gestion plus rationnelle du milieu paysannal.

Les paysans étant réticents à la culture des légumineuses essentiellement fourragères il est nécessaire de leur proposer celle des légumineuses ayant des graines commestibles, en plus du caractère de production d'une bonne biomasse.

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Benefits of Crop Rotation with Soybean and Cowpea in Savanna Cereal Based Systems

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Abstract

Results of research in the West African savannas to quantify benefits of rotation of soybean and cowpea to cereal-based systems are reviewed. N contribution from soybean and cowpea to a subsequent crop varies from 0 to 80 kg N ha^{-1}. The contribution depends on the effectiveness of the legume-Rhizobium symbiosis, legume growth duration, and legume residue management. The residual N effect increases with increasing amounts of N from atmospheric N_2 fixation as well as with increasing amounts of biomass N left after harvest.

Field tests with cultivars of cowpea and soybean selected for their efficacy in germinating *Striga hermonthica* seeds have shown substantial benefit in reducing levels of *S. hermonthica* infection on both sorghum and maize. Cultivars of these legumes varied in their effects because *S. hermonthica* has site specific strains. Field screening for efficacious cultivars is inefficient and is inferior to laboratory screening which uses a simple, inexpensive technique.

Résumé

Cette communication passe en revue les résultats de la recherche menée dans les savanes d'Afrique Occidentale pour quantifier les avantages de la rotation des légumineuses à grain, notamment le soja et le niébé, pour les systèmes à dominante céréalière. Les résultats de recherche révèlent que le soja et le niébé n'apportent pas toujours N à une culture céréalière subséquente. Ils indiquent cependant à quel moment l'on peut s'attendre à obtenir un profit substantiel et comment accentuer ce profit par la gestion.

Les essais au champ conduits avec du niébé et du soja sélectionnés pour leur efficacité à faire germer les semences de *Striga hermonthica* ont fait ressortir un avantage considérable en ce sens que les niveaux d'infection de *S. hermonthica* sur le sorgho aussi bien que le maïs ont été réduits. Néanmoins, les cultivars de ces légumineuses n'ont pas tous le même effet et *S. hermonthica* a des souches et des races spécifiques à des sites. Par ailleurs, le criblage effectué au champ pour obtenir des cultivars efficaces s'avère trop inefficace pour introduire en milieu paysan de bons matériels en une courte période de temps. Les programmes nationaux de recherche devraient plutôt être encouragés à commencer en laboratoire la sélection de cultivars pour une germination effective des semences de *S. hermonthica*. Une technique de laboratoire simple, peu

onéreuse et éprouvée permettant de cribler des cultivars de légumineuses efficaces pour lutter contre *S. hermonthica* a été mise au point par l'IITA et peut être facilement introduite dans les programmes nationaux de recherche.

Introduction

Improved grain legume-cereal rotation systems should be based on contributions of the grain legume to the subsequent cereal crop. Two major constraints to cereal crop production in the savannas of West Africa are N deficiency and *Striga hermonthica* parasitism. Soybean and cowpea cultivars should be chosen for rotation with cereals based on N benefit and reduction of *S. hermonthica* seedbank. A review of past work in these areas is presented in this paper.

Nitrogen Benefit to Subsequent Cereals

Nitrogen contribution by legumes to another crop occurs as a result of fixation of atmospheric N_2 by *Rhizobium* spp. in symbiosis with the legume, followed by decomposition of the legume plant organs (roots, nodules, leaves, stems). It is widely assumed that grain legumes such as cowpea and soybean contribute N to the soil and subsequently to the next crop, but the contribution is highly variable. In some cases it is substantial (Dakora *et al.*, 1987; Horst and Hardter, 1994; Kaleem, 1993) while in others it is less than the limit of detection in field trials or even negative (Jones, 1974). The contribution depends on species, cultivar, soil, climate and management factors.
The potential N contribution to a subsequent crop depends on the total amount of N (derived from legume-*Rhizobium* symbiosis) in the legume residues left in the field after harvest. It can be estimated from: (i) the total N content of the legume, (ii) the percentage of total N derived from atmospheric N_2 fixation (%Ndfa), and (iii) the amount of N removed in the harvest. For a crop where only grain is harvested, the N removed in the harvest is the N harvest index (NHI). Generally, if the NHI is less than the %Ndfa multiplied by the total N content, a N contribution can be expected. NHI greater than total N content derived from atmospheric N_2 fixation indicates soil N depletion by the legume crop.
Past work done on soybean and cowpea is reviewed below to help guide development of grain legume - cereal rotation systems. In West Africa, much more work has been done with cowpea than with soybean since the former is an indigenous crop.

Soybean

Estimates of N_2 fixation have ranged from 26 to 188 kg ha^{-1} in the tropics (Giller and Wilson, 1991). These quantities represented 70 to 90 % of the N in the above ground soybean dry matter. Many factors are responsible for this variability. Major plant characteristics which determine the amount of N_2 fixation are plant growth duration, vigour, nodulation, physiology of N_2 fixation, and soil or fertilizer N use (Giller and Wilson, 1991).
Even high N_2 fixation may not guarantee N accrual to soil and subsequent cereal. Soybean is a plant which is very efficient at translocating photosynthate and N to the grain. For example, Eaglesham *et al.* (1982) found more N in harvested grain than the estimated amount fixed by indeterminant soybean cultivars harvested 80 days after

planting (Table 1). They calculated very low contributions of 10 to 25 kg N ha^{-1} when fertilizer N addition was low and definite depletion of soil N when 100 kg N ha^{-1} was applied as fertilizer. The soybean crop was not followed by a cereal test crop to validate this prediction.

Table 1. Components of N balance (kg ha-1) for two soybean cultivars estimated by Eaglesham et al. (1982).

Cultivar	Mineral N uptake	Calculated N2 fixed	Total N above ground	Grain N removal	N in residues
N59-5253	28	188	216	204	12
Williams	23	120	143	141	2

The NHI is an indicator of the potential N supply to a subsequent crop. A smaller harvest index indicates a larger proportion of N left in the soil after grain harvest. Some workers measure the aboveground harvest index (N in harvested grain/total aboveground N) which is much easier to measure than the total NHI, but it underestimates the amount of N left to a subsequent crop, since root N is not included. Above ground NHI values for soybean are generally in the range of 75 to 90% (Eaglesham *et al.*, 1982).

Soybean is a relatively new crop to tropical Africa but it holds much promise. As soybean varieties are being developed for sustainable cropping systems, they need to be systematically screened for their contribution to a succeeding crop. The N contribution to subsequent cereals should be compared to the amount of applied N as fertilizer which results in a cereal grain, or total dry matter yield, equivalent to that produced by the cereal test crop when grown after the legume without added N. An example of this type of information is given in Table 2 for several grain legume crops, including soybean. This kind of screening should be done using elite soybean cultivars. Care must be exercised in the choice of preceding crop. As can be seen in the example, maize as a preceding crop might have overestimated the effect of the previous legumes because of its ability to deplete the soil of available N and/or because its high C/N residues can promote immobilization of soil N. The choice of preceding check crop should be governed by the options available to farmers. An uncropped check should be considered if fallow is an option available to farmers for soil fertility improvement. In some cases, two sets of checks might be used.

A disadvantage of testing the cultivars in rotation is that a second year of experimentation is needed. If only one year is available then the next best option is to estimate N_2 fixation using an appropriate reference crop (non-fixing with similar duration and rooting depth). Ideally, total N harvest index should also be measured to give a real indication of potential N contribution to a subsequent crop. Simple methods of sampling and estimating roots and nodules can be used to obtain the below ground contribution to total plant N content.

Table 2. Contribution of grain legumes to a subsequent maize crop in northern Ghana compared to N fertilizer (in kg ha-1) (From Kaleem, 1993).

Previous crop	N applied to subsequent maize	Maize grain yield (kg ha^{-1})
Maize	0	850
Bambara groundnut	0	2900
Groundnut	0	3750
Cowpea	0	3100
Soybean	00	3350
LSD $_{0.05}$		95
Yam	0	1800
Yam	20	2550
Yam	40	3200
Yam	80	4100

Notes: All crop residues were incorporated into the soil before maize planting. No error term was published for the maize yields following yam.

Soybean plants are often manually harvested by pulling up the plants and transporting them to an area where threshing is done. Residues are rarely returned to the soil. Thus, the major plant organs contributing N to the soil and subsequent crop are the remaining roots, nodules, and leaf litter which fell before harvest. Results from a study of the contribution of soybean in several sites in the Guinea savanna of Nigeria show that even when soybean residues are removed from the field, the effect on a subsequent maize crop is measurable (Table 3). The residual effect of medium duration variety (TGx1660-19F) was greater than that of the short duration variety (TGx1456-2E).

Table 3. Effect of 1993 soybean and 1994 fertilizer (in kg ha^{-1}) on 1994 maize grain yield in 10 sites in the guinea savanna of Nigeria.

Previous crop	N applied to subsequent maize	Subsequent maize yield (t ha^{-1})
Maize	20	2.35
Maize	60	3.50
TGx1456-2E	20	2.89
TGx1660-19F	20	3.56
LSD$_{0.05}$		n.s.

Cowpea

Worldwide, tropical estimates of N fixation by cowpea (9 to 201 kg N ha^{-1}) are even more variable than those of soybean (Giller and Wilson, 1991). Estimates from West Africa were 47 to 201 kg ha^{-1}, representing 54 to 76 % of total aboveground N. An important indicator of potential N fixation appears to be growth duration. Eaglesham *et al.* (1982) found N fixation by cowpea to increase in the order, determinate < semi-determinate < indeterminate. While Eaglesham *et al.* (1982) did not examine the effects of the different cowpea varieties on a subsequent test crop; this was done by Stoop and van Stavern (1982) in Burkina Faso. They found that millet grain yield increased with increasing plant density and increasing duration of the previous cowpea crop.

The NHI of cowpea is generally lower than that of soybean. In a trial where the aboveground NHI of two soybean varieties was greater than 95 %, comparable values for cowpea ranged from 37 to 60 % (Eaglesham *et al.*, 1982). Thus, cowpea is more likely than soybean to leave N in the soil for the subsequent crop. Within cowpea variability is substantial, however. Eaglesham *et al.* (1982) reported aboveground harvest indices of 37 % for an indeterminate variety, 54 % for semi-determinate, and 59 to 60 % for two determinate varieties. Aboveground NHI of TVx 4569-C-IK (60 days to maturity) cowpea at Nyankpala, northern Ghana, varied from 40-49 % (Horst and Hardter, 1994).

A summary of results of field trials from the savannas of West Africa suggests substantial N benefit of cowpea to a subsequent maize crop. Horst and Hardter (1994) left residues from two short duration cowpea crops on the surface of plots on which maize was then grown in the following year. The yield of maize following cowpea was higher than that of maize following maize and fertilized with 80 kg N ha^{-1} (Table 4). This is the only report from the West African savanna which comes from two cycles of experimentation. In the second year, the responses to N fertilizer and a previous crop of cowpea were reduced.

Dakora *et al.* (1987) rototilled cowpea residues into the soil and found subsequent unfertilized maize yield to be equivalent to that of maize fertilized with approximately 60 kg N ha^{-1} (as ammonium sulfate) following a previous crop of maize (Table 5). This trial was only conducted for one year in one site and the response to N in the maize crop was not consistent. Likewise, the results of Kaleem (1993) allow estimation of the fertilizer N value of a previous cowpea crop equivalent to 40 kg ha^{-1} to maize following yam (Table 2). It is not clear whether the previous yam check plots were replicated as part of the experimental area.

Table 4. Effect of previous cowpea crop and subsequent year fertilizer N (kg ha^{-1}) on subsequent year maize grain yield (t ha^{-1}) (estimated from Figure 1 of Horst and Hardter, 1994).

Previous crop	1985 N applied	1985 Maize yield	1986 N applied	1986 Maize yield
Cowpea	0	2.7	0	2.7
Maize	0	1.8	0	2.2
Maize	80	2.4	80	2.6
$LSD_{0.05}$		0.45		0.45

The difference in N fertilizer equivalents between the studies appears to be understandable. The highest value, about 80 kg N ha^{-1} (Horst and Hardter, 1994) came from two crops of cowpea grown in the first and second growing seasons of the first year followed by maize in the second year. The second highest estimate, approximately 60 kg N ha^{-1} (Dakora *et al*., 1987) came from first season cowpea followed by second season maize, with cowpea residue incorporated into the soil. The lowest estimate of 40 kg N ha^{-1} (Kaleem, 1993) came from first year cowpea (one crop) followed by second year maize.

Table 5. Effect of previous legume crop and subsequent year fertilizer N (kg ha-1) on subsequent year maize grain yield (Dakora et al., 1987).

Previous crop	N applied to subsequent maize	Maize grain yield (t ha^{-1})
Cowpea	0	1.80
Groundnut	0	1.85
Maize	0	0.95
Maize	30	1.39
Maize	60	1.87
Maize	90	1.31
Maize	120	1.47
$LSD_{0.05}$		0.66

In the above trials, cowpea residues were left on the soil surface (e.g., Horst and Hardter, 1994) or even incorporated into the soil (e.g., Dakora *et al*., 1987). However, cowpea vines are often collected for dry season fodder in the Guinea savanna. In some trials to evaluate rotation effects of cowpea, aboveground cowpea residues have been removed to simulate harvesting of vines for fodder.

Nnadi *et al*. (1981), working at Samaru in northern Nigeria, grew three varieties of cowpea and removed the residue from the field after grain harvest. They recorded higher yields of maize following cowpea cultivars, Ife Brown (2.6 t ha^{-1}) and NEP 593 (3.1 t ha^{-1}) than following a previous crop of sorghum (1.9 t ha^{-1}). NEP 593 was shown in another study (Nnadi and Balasubramanian, 1978) to have a much higher root N concentration (2.5 %) than Ife Brown (1.5 %). In laboratory incubation, NEP 593 released inorganic N from the beginning and Ife Brown roots immobilized soil inorganic N during the early incubation phase. Results like these may explain why the effect of a preceding cowpea crop on a subsequent cereal has been nearly undetectable in some cases as experienced by Jones (1974) working with one variety at Samaru.

Striga hermonthica Seedbank Reduction

Reduction of soil reserves of *S. hermonthica* seeds is the cornerstone of any effective *S. hermonthica* control strategy. *S. hermonthica* seeds germinate only after the seeds have been exposed to the proper temperature and moisture conditions and subsequently to a germination stimulant. In the absence of a suitable host, *S. hermonthica* seedlings die several days after germination. A promising approach to reducing soil levels of *S. hermonthica* seeds is the use of non-host rotational crops (Doggett, 1984; Parkinson et al., 1987). Some commonly grown crops, like cotton and cowpea, are not hosts for *S. hermonthica*, but the root exudates of these crops can stimulate parasite seed germination. Very little research has been done to identify the more potent *S. hermonthica* germination inducers among crops/crop varieties.

Screening and identification of effective rotation crops has been tried under field conditions (Parkinson *et al.*, 1987) but the process generally requires two or more seasons to establish uniform *S. hermonthica* infestation, grow the trap crop and evaluate with a susceptible host the following season. When these problems are considered together with large variability in *S. hermonthica* seed soil densities, field screening has little promise in the development of *S. hermonthica*-suppressive cropping systems.

To overcome the above problems, a laboratory procedure using cut roots of non-hosts to test for plant efficacy in stimulating *S. hermonthica* seed germination was developed (Dejongh *et al.*, 1993; Berner *et al.*, 1993). The technique requires only a minimum of laboratory materials and equipment (namely, stereo microscope with 30X magnification, autoclave or steam sterilizer, petri dishes, hand-held counters, forceps, filter paper, small pots). To do this, surface sterilized *S. hermonthica* seeds are placed on 8-mm glass-fiber filter paper discs (25-30 seeds/disc) placed on moistened filter paper in petri dishes. Seeds are conditioned by incubating at 30°C in darkness for 10 days. Roots of 7-day-old seedlings of the test plant are cut into 1-cm pieces, weighed and placed into a 2-cm-diam. aluminum ring centered on moistened filter papers in a petri dish. Glass-fiber disks with the conditioned *S. hermonthica* seeds are placed around the central ring in four radii of three concentric rings with the first one touching the stimulant source. After incubating for 48 hours at 30°C, per cent *S. hermonthica* seed germination is determined. Distances from the germination source and root weight are used as covariates in analyses of cultivar differences (Berner *et al.*, 1993).

Soybean

Using the above technique, Alabi *et al.* (1994) have demonstrated significant differences among 55 soybean cultivars in their efficacy to stimulate *S. hermonthica* seed germination (Table 6).

Table 6. Summary of variability in germination of *S. hermonthica* seeds induced by cut roots[a] of soybean cultivars (Alabi *et al.*, 1994).

Cultivar	Relative germination (%)[b]	Standard error
TGx1649-11F	63.4	2.75
TGx1707-4E	53.6	2.43
TGx1660-15F	52.4	2.58
	-	-
-	-	-
	-	
TGx1485-1D	20.9	4.21
TGx1648-3F	20.0	3.65
TGx1660-18F	17.5	2.76
Deionized water	17.2	4.21

[a] One gram of cut roots of each cultivar was used in analysis.

[b] Germination relative to 10 ppm of a synthetic germination stimulant

The distribution of the 55 cultivars with respect to efficacy in stimulating *S. hermonthica* germination was apparently normal, indicating the potential for selection of highly efficacious cultivars. However, given the great variability among the cultivars in ability to stimulate *S. hermonthica* seed germination, it would certainly be a mistake to recommend planting soybean to control *S. hermonthica*, if the cultivar being planted had no greater efficacy than distilled water. Thus cultivars, as well as crops, need to be screened for efficacy in germinating *S. hermonthica* seeds.

To validate results of the laboratory screening, a three year field trial was established with a selected subset of four of the soybean cultivars tested in the laboratory. In this trial, local sorghum was planted in a *S. hermonthica* infested field following a crop of either sorghum or one of the selected soybean cultivars in the previous season. Preliminary results indicate that germination induced by cut roots of the cultivars in the laboratory correlated with *S. hermonthica* emergence ($r = -0.96$) and sorghum straw yield ($r = 0.96$). Based on the correlations already obtained between laboratory and field results, the laboratory screening technique appears to be an excellent tool for selecting efficacious germplasm.

Because soybean leaves senesce, drop, and contribute to under-canopy litter during the growing season, the contribution of leaves to *S. hermonthica* seed germination may be an important adjunct to germination stimulation by soybean roots. Using the technique described above, leaves and stems of soybean cultivars were tested for efficacy in stimulating *S. hermonthica* seed germination (Ariga *et al.*, 1994). There was again considerable variability among cultivars in efficacy to stimulate *S. hermonthica* seed germination (Figure 1). This variability was constant for the three isolates of *S. hermonthica* seeds used, indicating stability of efficacy across locations. The range of germination varied from greater than that induced by the synthetic stimulant, GR24, to the same as distilled water. Thus, selection of cultivars must be carried out before recommendations can be made. If the stimulant ability of the leaves of the highly effective cultivars remains constant, over the life of the soybean plant, then their contribution to *S. hermonthica* seed germination, and reduction of parasite seed densities in the soil, may be substantial and an important additional selection criterion for soybean.

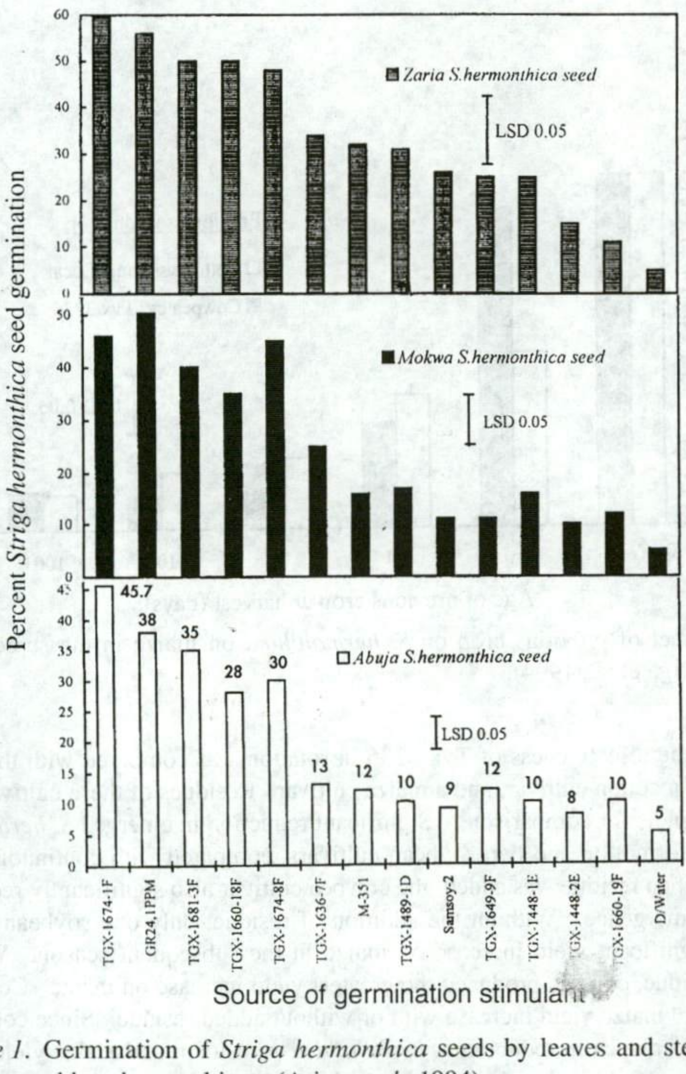

Figure 1. Germination of *Striga hermonthica* seeds by leaves and stems of 10-day-old soybean cultivars (Ariga *et al.*, 1994).

Cowpea

Using the same laboratory technique, cowpea cultivar, TVx 3236, highly effective in stimulating *S. hermonthica* seed germination was selected for screenhouse and field tests (Ariga *et al.*, 1994). In the screenhouse, TVx 3236 was compared with a cultivar of cotton, Abuja local, known to be effective in stimulating *S. hermonthica* seed germination. Results are shown in Figs 2 and 3. A significant reduction in attached *S. hermonthica* and a significant yield increase was found on the maize crop following only ten days growth of the cotton cultivar. After 40 days growth both cowpea and cotton cultivars significantly reduced *S. hermonthica* attachments and increased yield on the subsequent maize crop. After 40 days there were no significant differences between the cotton and cowpea cultivar in either *S. hermonthica* attachments or yield of the subsequent maize crop.

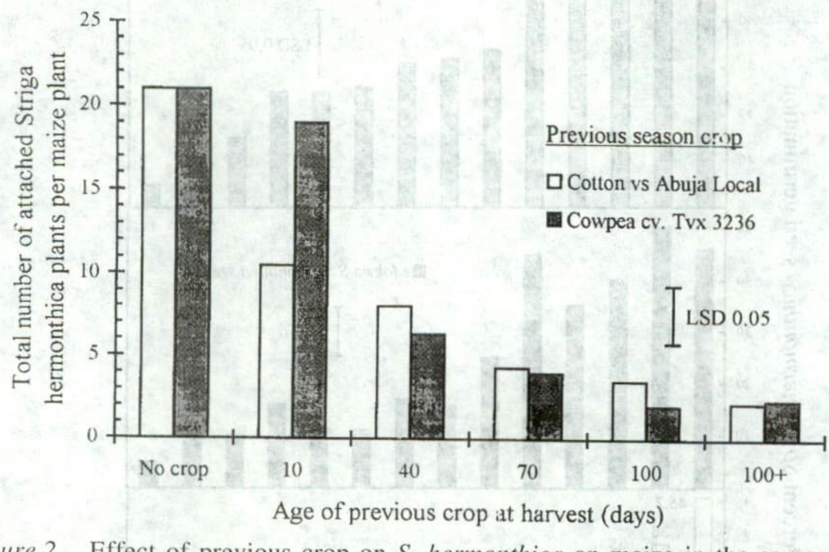

Figure 2. Effect of previous crop on *S. hermonthica* on maize in the screenhouse (Ariga et al., 1994).

In field tests, the effectiveness of Tvx 3236 in rotation was compared with three soybean cultivars, a cotton cultivar, and a maize cultivar. Residues of these cultivars were also placed in plots for comparison. Significant reduction in emerged *S. hermonthica* was observed for cotton and two soybean cultivars, compared with continuous maize cultivation. When residue was added, the cowpea cultivar also significantly reduced *S. hermonthica* emergence. Without the addition of residue, only one soybean cultivar produced a significant yield increase on maize in the subsequent season. With the addition of residue, cowpea produced the greatest yield increase on maize. Cotton failed to produce a maize yield increase with or without added residue. Since cotton was as effective as cowpea in reducing *S. hermonthica* parasitism and maize yield loss in the screenhouse, the difference in the field results are likely due to N fertility benefit of cowpea. However, the results of the screenhouse and field trials indicate that effective

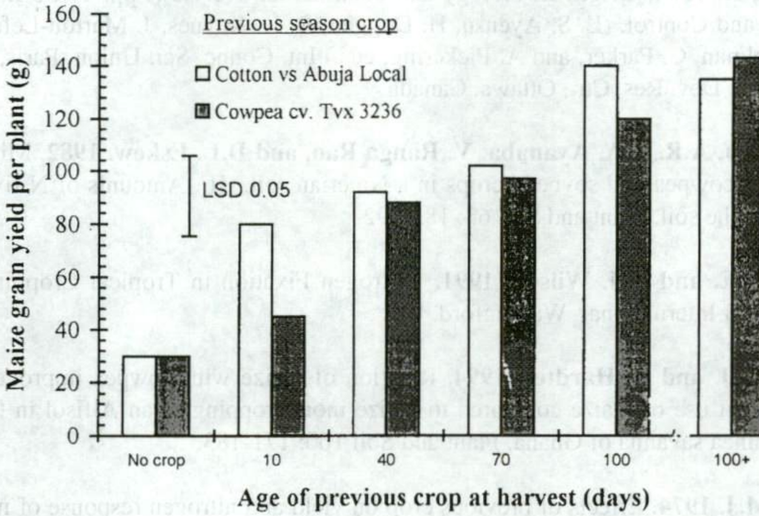

Figure 3. Effect of previous crop on maize grain yield in the screen-house

cowpea cultivars can be selected in the laboratory to provide control of *S. hermonthica* through rotations as effective as cotton - a standard rotation for *S. hermonthica* control.

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Production Durable des Systèmes Céréales/légumineuses en Zone Savane de Côte d'Ivoire

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Résumé

Les légumineuses comme plantes de couverture peuvent largement contribuer à couvrir les besoins en azote des céréales et autres plantes non fixatrices. En plus, elles assurent la couverture du sol entre les cultures, réduisent l'érosion et éliminent les mauvaises herbes. Elles améliorent également les qualités physiques du sol et peuvent significativement réduire la population de certains parasites comme les Nématodes.

Malgré ces avantages, l'utilisation des légumineuses comme engrais vert ou autres dans les systèmes de production de céréales en zone de savane en Côte d'Ivoire n'a pas pour plusieurs raisons été véritablement répandue en milieu paysan. Néanmoins ces données expérimentales indiquent que *Pueraria, Mucuna, Crotalaria, Calopogonium* produisent une importante biomasse. La bonne gestion de ces cultures pourrait améliorer les rendements aussi bien de riz que de maïs. Des études en cours tentent de teminer le rôle des légumineuses dans l'amélioration des jachères de courte durée pour une production agricole durable et économiquement viable en milieu paysan.

Abstract

Legumes used as cover crops can largely contribute to meet plant nitrogen requirements particularly for cereals and other non nitrogen fixing plants. Furthermore, they ensure soil cover between the cropping cycles, reduce erosion and control weeds. They improve the soil physical quality and may significantly reduce the population of some pests such as nematodes.

In spite of these advantages, the use of legumes generally in cereal production systems in the Savana zones of Côte d'Ivoire has not been widely spread among farmers. Nevertheless, these data indicate that some species such as *Mucuna, Gliricidia, Calopogonium* produce a great biomass. Their good management has improved both rice and maize yields. Recent studies try to determine the role of legumes in improving short duration fallow for a sustainable and economically viable agricultural production for farmer.

Introduction

L'Afrique sud-saharienne qui est la seule région au monde où la production alimentaire est en baisse constante ces dernières années, doit pour s'en sortir, faire face à deux défis, à savoir:

- Comment augmenter rapidement la production alimentaire face à l'augmentation de la population estimée à 2% par an en zone rurale (ADRAO, 1992).

- Comment éviter de dégrader les sols et l'environnement en voulant atteindre cet objectif de production agricole accrue par rapport aux besoins.

Parmi les différentes possibilités, l'intensification de l'agriculture s'avère être une voie incontournable quand on sait que l'élément le plus important responsable de rendement élevé dans une culture de céréale est l'azote minérale. Cependant son utilisation dans les systèmes céréaliers en Afrique de l'Ouest est très faible; en moyenne inférieur à 10 kg/ha (Mudahar, 1985). Lorsqu'il est appliqué, son efficacité est tout aussi faible. Sur le riz par exemple, en Afrique de l'Ouest, l'efficacité d'utilisation de l'azote minérale est de l'ordre de 12 kg de grains de riz par kilogramme additionnel d'azote appliqué alors qu'en Asie on obtient jusqu'à 20 kg dans les bas-fonds rizicoles (Tableau 1) (Becker *et al.*, 1994).

Tableau 1. Comparaison de moyennes de rendements

A/ Bloc F (sur sol gravillonnaire)

Légumineuses	30 JAS			56 JAS			105 JAS	
	B.A	L.R.	P.A.	P.A.	B.A.	L.R.	P.A.	P.A.
Mucuna	235 a	22 a	143 a	1088 a	172 a	270 b	1538 b	200 a
Calopogonium	120 b	19,9 b	168 a	425 c	58 b	737 a	1538 b	318 a
crotalaria	122 b	17,2 b	143 a	750 b	44 b	295 b	2375 a	362 a
CV	30,65	14,38	31,44	20,7	20,4	33,02	19,52	43

B/ Bloc D (sur sol hydromorphe)

Légumineuses	30 JAS			56 JAS			105 JAS	
	B.A	L.R.	P.A.	P.A.	B.A.	L.R.	P.A.	P.A.
Mucuna	183 a	22a	140 a	638 ab	93,3 a	213 c	1825 b	175 b
Calopogonium	120 b	15,9b	160 a	263 b	36,6 a	803 a	750 c	519 a
crotalaria	165 b	14,8b	145 a	1093 a	43 a	563 b	2588 a	244 b
CV	21,4	15,63	31,5	50,4	56	20	12,03	24,9

B.A. Biomasse aérienne sèche en centimètres

L.R. Longueur racinaire en centimètres

P.A. Poids sec des adventices en grammes

JAS. Jours après semis.

Dans les zones savanes de Côte d'Ivoire, les systèmes de production tournent autour d'une culture principale qui est soit le coton, l'igname ou le riz. Les principales céréales rencontrées sont le riz, le maïs, le mil, le sorgho et secondairement le fonio. La production de légumineuses occupe environ 10% des terres cultivées *(Arachis hypogaea)*, du niébé (*Vigna unguiculata*), du voandzou (*Vigna subterranea*) et du soja (*glycine max*).

Les types de sols prédominants sont:

- Les lithosols qui couvrent environ 39 % dans la région de Boundiali et 18 % à Korhogo et Ferkessédougou.

- Les vertisols qu'on retrouve au niveau des bas-fonds et plaines alluviales (2 % des sols à Ferké et Korhogo et 4 % à Boundiali).

- Les sols ferrugineux qui couvrent 70 % des superficies.

Dans ces zones, les principales carences observées comme dans la plupart des pays d'Afrique de l'Ouest sont l'azote et le phosphore (Gigou, 1992).

Pour faire face aux besoins alimentaires à long terme, la production en céréales doit être intensifiée de façon à améliorer la production par unité de surface. Tous les intrants (internes ou externes) doivent être utilisés efficacement pour une production durable. L'intensification des systèmes de cultures et l´augmentation de la productivité des sols tout en préservant les ressources de base nécessitent une approche collaborative. En ce qui concerne l'IDESSA, une des opérations de recherche dans le cadre de la stabilisation de l'agriculture en zone de savane est l'amélioration ou le maintien de la fertilité des sols avec introduction de légumineuses pour non seulement améliorer le bilan azote du sol et le taux de matière organique mais aussi réduire le coût de l'exploitation auquel le paysan doit faire face. Dans ce document, l'accent sera porté essentiellement sur les légumineuses de couverture pour lesquelles de nombreuses perspectives de recherche se développent actuellement. Elles ont l'avantage de former en plus un mulch épais qui peut être contrôlé (herbicides, fauche, roulage..) avant le semis des cultures. Ce mulch permet de contrôler l'érosion en limitant les pertes par ruissellement, de diminuer les pertes par évaporation, d'offrir la possibilité de faire des semis échelonnés directement sans travail du sol, d'apporter de l'azote, d'augmenter la vie biologique et le taux de matière organique dans les horizons superficielles (Charpentier, 1995).

La recherche sur les systèmes céréales/légumineuses est assez récente en zone savane de Côte d'Ivoire. Notre objectif est de faire une brève synthèse des premiers résultats obtenus.

Matériels et Méthodes

L'étude s'est faite à la station de Recherche de Ferkessédougou. Situé dans la zone savane du Nord de la Côte-d'Ivoire, elle est caractérisée par un régime pluviométrique unimodale avec des précipitations comprises entre 900 et 1350 mm. A Ferké, on atteint 1 350 mm (tableau 2). Les sols dominants sont de type ferrugineux avec présence de gravillons plus ou moins grossiers. Les pentes peuvent atteindre 10%. L'altitude est de 350 mètres. En 1990, une collection de 26 espèces de légumineuses de couverture a été évaluée pour leur aptitude à se développer et à couvrir le sol et aussi pour leur longévité en saison sèche. Trois espèces de cette collection (Calopogonium, Mucuna, Crotalaria) ont été semées sur des parcelles de 50 m^2 en condition de plateau sur un sol gravillonnaire ferrugineux (bloc F) et sur un sol sablo-argileux (bloc D) situé en bas de pente avec un niveau d'hydromorphie plus élevé. Le dispositif utilisé est un bloc complet randomisé avec 4 répétitions. La biomasse aérienne sèche a été mesurée à 28, 56, 105 jours après semis, de même que le poids sec des adventices présents par mètre carré de superficie du champ d'essai. Un échantillon de 10 plants a servi à mesurer la profondeur racinaire à 28 et 56 jours, respectivement.

Résultats

L'évaluation de la collection montre que des 27 espèces testées, 10 ont survécu jusqu'au 10 février ou au-delà (tableau 1). Il s'agit de *Macroptilium atropurpureum, Canavalia ensiformis* (rouge), *Canavalia ensiformis* (perdrix), *Tephrosia elegans, Casia hirsuta, Crotalaria goreensis, Zornia glorehydiata, Crotalaria retusa, Centrosema pubescens, Ipomea eriocarpa*. Les 17 autres sont des espèces annuelles qui ont terminé leur cycle avant la période sèche de décembre. La capacité des différentes espèces de légumineuses à se développer et à couvrir le sol est très variable. Certaines ont une croissance initiale lente comme le *Calopogonium, Téphrosia, le Desmodium*. Ce sont généralement des légumineuses à petits grains, par contre d'autres ont une croissance rapide (*Mucuna, Pueraria, Stylosanthes, Crotalaria*) leur permettant de développer une biomasse végétale importante avant l'apparition des mauvaises herbes. Des résultats similaires ont été obtenus au Brésil où 52 espèces ont été testés (Marilia et Allert, 1992). Le développement des légumineuses et leur capacité à survivre pendant la période sèche sont des critères à considérer pour envisager leur mode de gestion et leur intégration dans le système agricole. Des espèces pérennes comme Centrosema et Pueraria résistent assez bien en période sèche et leur développement reprend immédiatement dès les premières pluies en avril.

La production de biomasse et les effets sur les mauvaises herbes ont été estimés sur 3 espèces (*Mucuna, Calopogonium et Crotalaria*). Nos résultats montrent qu'en conditions hydromorphes (bloc D) 30 jours après semis, la production de masse végétale est équivalente pour les 3 espèces; mais à partir du 56^{ième} jour jusqu'au 105^{ième} jour, le Mucuna et le Crotalaria vont développer une matière sèche (MS) végétale importante qui va entraîner une réduction sensible du taux d'enherbement des parcelles (tableau 2). En condition de plateau après un mois, le *Mucuna* avait produit 235 kg/ha contre 120 kg/ha de matière végétale obtenue par le *Crotalaria*. Mais au 105^{ième} jour après semis, seul le *Crotalaria* semble dominer les autres espèces. Ceci montre que dans de bonnes conditions agro-climatiques, on peut produire une biomasse importante de légumineuses. C'est le cas du Crotalaria (MS > 2,5 t/ha) et du Mucana (MS > 1,8 t/ha). Cette production peut être améliorée avec des semis plus précoces et sous une bonne pluviométrie (Marilia et Allert, 1992).

La capacité du Calopogonium à contrôler les mauvaises herbes est limitée en début de cycle. Cela est dû à sa lente croissance entraînant une couverture insuffisante du sol. Toutefois il semble mieux adapté en conditions de plateau qu'en zone hydromorphe (figures 1 & 2). Le Crotalaria assure une bonne maîtrise des mauvaises herbes (figure 1) sans toutefois être une espèce rampante. Le contrôle des mauvaises herbes par les légumineuses fait l'objet d'études. D'autres espèces telle que *Sesbania sesban* sont aussi efficaces sur les adventices (Ngiumbo et Balasubramanian, 1992). Cette action qui est due à une compétition entre les espèces végétales peut être aussi attribuée à des effets alléopathiques (Midmore, 1993). Néanmoins, une gestion judicieuse des légumineuses dans un système intercalaire avec le riz et le maïs permet d'augmenter les rendements et faire des économies de main-d'oeuvre (Charpentier, 1990).

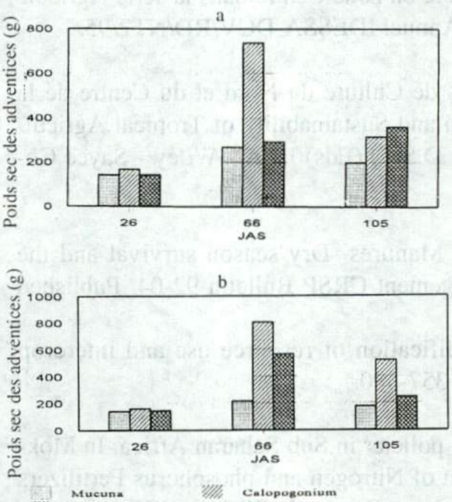

Figure 1. Effet des légumineuses sur le développement des adventices (a) sur plateau et (b) sur sol hydromorphe.

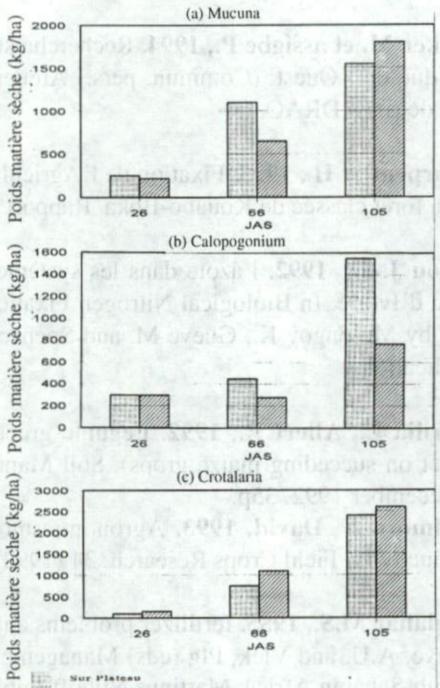

Figure 2. Croissance des légumineuses sur plateau et sol hydromorphe

Conclusion

Bien que préliminaires, cette étude montre que le Mucuna et le Crotalaria tolèrent mieux les conditions de forte humidité que le Calopogonium dont la matière sèche végétale chute littéralement de 1537 kg/ha à 750 kg/ha lorsque l'humidité du sol est plus élevée. De même, leur action sur la flore adventice essentiellement constituée de graminées est variable, 56 jours après les semis ; la plus grande quantité d'adventices étant dans les parcelles de Calopogonium. Néanmoins, il convient de noter que l'impact des légumineuses sur la production des céréales ne peut se mesurer que dans le temps, car, il implique le développement de stratégies qui intègrent le système agricole dans sa totalité (Agronomique et Socio-économique). Les résultats acquis àce jour ne permettent pas de tirer des conclusions sur la durabilité des systèmes de production de céréales/légumineuses en zone savane Côte d'Ivoire. Cependant, des données sur le mode de gestion (non présentées) et celles relatives au criblage et à la production de biomasse existent. Des études complémentaires et l'évaluation économique des nouvelles technologies méritent d'être approfondies et poursuivies afin de rendre leur utilisation plus économiquement rentable aux producteurs.

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Sustaining Food Production in Ghana: the Role of Cereal/Legume Based Cropping Systems

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Abstract

This paper examines yield, profitability and soil management as major aspects of sustainable food production in Ghana as they relate to cereal/legume-based cropping systems. Current farmer traditional practices can no longer sustain production and productivity; increasing population pressure on land, market demand, soil fertility decline, dependency on erratic rain-fed agriculture with frequent droughts demand technology intervention for sustainability. Research on productivity and sustainability of cropping systems is beset with many constraints. However, experience in Ghana with crop rotation systems demonstrates clearly that cowpea, a legume, leaves an equivalent of 37 kg N/ha to a subsequent maize crop. This excludes the above-ground residue which has been estimated to be even higher than this value. Land equivalent ratio (LER) values of 1 and above have been obtained for maize/cowpea intercrop systems, with over 60% higher net benefit than when each crop component is planted as a monocrop. A four-crop intercrop combination of maize/cassava/soybean/cowpea has been demonstrated to be a feasible option to take care of crop intensification, without the attendant yield decline. A low-input alley cropping technology, based on multipurpose leguminous species used as mulching materials for plantain, indicates the usefulness of *Flemingia congesta* in suppressing parasitic nematode populations, preservation of soil moisture and decreasing soil temperature. Control of persistent weeds under such culture will reduce the farmer's labour expenditure and yield loss.

Résumé

La présente communication examine le rendement, la rentabilité, la gestion du sol et autres alternatives comme aspects-clés de la production vivrière durable au Ghana se rapportant aux systèmes culturaux à dominante céréale/légumineuse. Les pratiques traditionnelles actuelles des paysans ne peuvent plus soutenir la production ni la productivité. La pression démographique croissante sur les terres, les exigences du marché, la baisse de la fertilité du sol, la dépendance vis-à-vis d'une agriculture alimentée par une pluviométrie incertaine, avec des sécheresses fréquentes, appellent l'introduction de technologies pour la durabilité. La recherche sur la productivité et la durabilité des systèmes culturaux est confrontée à de nombreuses contraintes.

Cependant, notre expérience au Ghana en matière de systèmes de rotation culturale démontre clairement que le niébé, une légumineuse, apporte un équivalent de 37 kg de N/ha à une culture subséquente de maïs, sans compter les résidus de surface dont

l'apport est jugé être encore supérieur à cette valeur. Des valeurs de LER (rapport équivalent terre) de 1 et plus ont été obtenues pour les systèmes d'association maïs/niébé, avec des bénéfices nets de 60 % supérieurs lorsque chaque composante culturale est semée en monoculture. Il a été démontré qu'une combinaison de quatre cultures associées - maïs/manioc/soja/niébé - était une option réalisable pouvant assurer l'intensification de culture sans une baisse concomitante de rendement. Une technologie de culture en couloirs nécessitant peu d'intrants et basée sur des espèces légumineuses à objectifs multiples utilisées comme matériaux de paillage pour le plantain fait ressortir l'utilité de Flemingia congesta pour supprimer la population de nématodes parasites, préserver l'humidité du sol et réduire la température du sol. La lutte contre les mauvaises herbes persistantes dans ces conditions culturales permettra de réduire le volume de travail des paysans et les pertes de rendement. Les réponses des paysans en ce qui concerne le rôle des différents sexes montrent l'importance du rôle des femmes dans le semis, la récolte, la transformation et la commercialisation des cultures vivrières. Il a été relevé que la population agricole était constituée à plus de 50 % de paysannes. Pour assurer la sécurité alimentaire, la recherche sur les systèmes culturaux impliqua maintenant la pleine participation des paysannes à l'identification des problèmes, à l'établissement des priorités, à la recherche de solutions, à leur mise en oeuvre et évaluation.

Introduction

It is doubtful whether subsistence agriculture could provide answers to the major food problems of Africa. These problems include: (i) inability of agricultural production to match the rapid population growth, resulting in a widening deficit in the food requirements of growing urban populations; (ii) a rural population vulnerable to crop failures due to periodic droughts, pest epidemics, and a degraded environment; and (iii) civil disturbances, and inappropriate monetary and fiscal policies, coupled with inefficient marketing, processing and other support infrastructure, resulting in major shifts in cropping patterns.

The 1983 Ghana Government's 'Economic Recovery Program' (ERP), provided for: a) market prices determined by supply and demand forces and a curtailment of public sector marketing; b) liberalized agricultural imports; and c) currency devaluations as an incentive to producers to grow tradeable commodities. Improved agricultural technology, with the farmer as one of the principal collaborators, however, offers excellent opportunities to solve problems affecting sustainable food production, although the farmer's low income hampers purchase of inputs.

Soil fertility regeneration and maintenance appear to be the most serious agronomic challenges to crop productivity in Ghana. They are likely to become more critical as the fallow periods get shorter. A shortened fallow period substantially increases the needs for fertilizers which are difficult to satisfy because subsidy removal has put the cost of inorganic fertilizers beyond the reach of the ordinary fermer. It has been estimated that it would require 332,000 mt of sulphate of ammonia and 116,000 mt of single superphosphate to replace the nutrients annually removed from the soil in Ghana (Bean/Cowpea CRSP, 1992). This contrasts with Ghana's total fertilizer import of only 45,000 mt in 1989. Appropriate production technology must respond to the fertility decline in the rural farming community where sufficient subsistence is the principal focus of food security (Dapaah, 1991). Ghana's required nutrients will continue to be supplied principally by regeneration of fertility under fallow and there is the need for continued research on appropriate grain-legume rotations, as the main input of nitrogen in the cropping systems, to reduce the demand for inorganic fertilizer (World Bank, 1991). It is worthwhile, therefore, to develop cropping systems that keep the fertilizer nitrogen budget to a minimum, while ensuring optimum crop yields. This paper examines soil management, yield and profitability, and alternative uses of produce, as key aspects of sustainable food production in Ghana as they relate to cereal/legume-based cropping systems.

Food Production in Ghana

Ghana's population of 15 million is projected to reach 18.6 million by the year 2000 due to its annual growth rate of 2.6% (ISSER, 1993). Without significant improvement in productivity, by the year 2000, the annual food deficit will widen to 200,000 tonnes from about 140,000 metric tonnes in 1989. Six agroecological zones are recognized in Ghana, namely, the Sudan savanna, the Guinea savanna, the forest-savanna transition intergrade, the semi-deciduous forest, the rain forest, and the coastal savanna. The mean annual rainfall is between 800-2800 mm while the duration of the growing season varies from 4 to 10 months. In the transition, humid forest, and coastal savanna zones, the main food crops include maize, cowpea, vegetables, yam, plantain, and cassava while the tree crops include oil palm and cacao. The soils of these zones are characterized by kaolinitic clay minerals, leaching of nutrients, and acidity. They are deeply weathered and easily eroded Acrisols of moderate fertility. In the northern Guinea savanna and the Sudan savanna, the main food crops are millet, sorghum, groundnut, cowpea, maize and yam. Soils in the Guinea savanna are mainly low fertility Luvisols, which are less leached, less acidic, but with less organic matter in the surface horizons. Here the food production problems include unpredictable and erratic rains, shallow soils with low organic matter and fertility, and compact subsoil layers.

The most widespread cultivation system is land rotation with a bush fallow, the length of which has reduced considerably, with consequent gradual decline in soil fertility.

The Cereal/Legume Based Cropping System

Sustainability in terms of adequate soil management

The low fertility of soils in Ghana has been partly attributed to: low nitrogen and phosphorus reserves because of the low cation exchange capacity of the mainly kaolinitic clay minerals; low organic matter content of most soils; and the sandy-textured surface horizons, especially in the Guinea savanna.

Generally, fields with relatively good fertility are planted with cereals, of which maize is the most popular. In the Guinea savanna, the poorer soils are planted with groundnut, soybean and rice, principally to satisfy the farmers' primary objective of meeting their staple food requirements. Rice is planted in lowlands/valley bottoms, located far away from the homes so that they do not receive farmyard manure. The use of inorganic fertilizer is low. The practice of continuous cropping limits the capacity of fallowing as a mechanism for restoring soil fertility. The legumes are rotated with cereals, where possible. However, the legume fields are so small in size that the legumes cannot effectively contribute to maintaining soil fertility.

The use of cow dung manure is minimal since it benefits only fields close to the homes in the Guinea and Sudan savanna zones. Recently, poultry manure has been used, especially in the forest zone but, like cow dung manure, it is bulky to transport. The use of compost is also not widespread. The situation is exacerbated by frequent, uncontrolled burning of crop residues and bush fires.

To arrest the above situation, the following soil management techniques, among others, will be required: crop rotations, legume based multiple cropping, alley cropping, use of lower slopes and inland valleys, minimum tillage, use of crop residues as mulch, appropriate planting densities, and appropriate choice of varieties and planting dates as a means to match phenology and expected water supply. The benefits of crop residues, rotations and intercropping, for example, have been demonstrated in Ghana (Asafu-Agyei, 1987) and could therefore be explored. The potential exists in Ghana for using the edible velvet bean, *Mucuna pruriens* var *utilis*, or "Adua apea" as it is known in Ghana, as a leguminous cover crop to restore fertility (Osei Bonsu, 1993).

Technology intervention through crop rotation

The length of the traditional food crop/bush-shrub-fallow is no longer long enough to restore the soil fertility under the farmer's present socio-economic conditions.
To develop an alternative technology to the bush-fallow system, a maize/cowpea rotation study was conducted from 1981-1984 to evaluate the effect on maize yields caused by continuous growing of maize and maize/cowpea rotations, with and without applied fertilizer, and to determine the degree to which cowpea could reduce the need to apply inorganic nitrogen fertilizer to maize. The trial was conducted at Kwadaso in the forest zone and Ejura in the transition zone of Ghana during six growing seasons (two seasons/year).

The results showed that maize grown without application of inorganic fertilizer after five successive cycles of cowpea out-yielded maize preceded by five successive cycles of maize by 1.71 t/ha. The beneficial effect of the preceding cowpea crop to maize is probably due to its ability to fix atmospheric nitrogen and the beneficial effects of the roots on soil structure. When fertilizer was applied to the maize, the crop preceded by cowpea yielded only 0.97 t/ha more than the crop preceded by maize. The beneficial effect of cowpea under these conditions was probably due to the effect of the roots in improving soil structure. The difference between the two values (i.e., 0.74 ton/ha) could be attributed to the effect of atmospheric nitrogen fixed by cowpea. If it is assumed that roughly 20 kg grain/ha was harvested for one kg N added to the soil, then the above 740 kg of grain would be equivalent to 37 kg N/ha. This was the amount of nitrogen the cowpea added to the soil (in different forms) and utilized by the subsequent maize crop. About 60 kg/ha of residual N fertilizer was reported to have been left to a subsequent maize crop by cowpea and groundnut in Guinea savanna zone of Ghana (Giller and Wilson, 1991). This is apart from the 68 kg N/ha left behind in above ground residues.

Technology intervention through multiple cropping

For the small-scale farmer, intercropping provides his food-security and income needs, even under the unpredictable rainfall regimes and eroded soil conditions.
A trial involving maize/cassava/soybean/cowpea multiple crop combination was conducted to: (i) maximize utilization of resources throughout the growing season, and (ii) to develop stable cropping systems for multiple mixtures of maize, cassava, soybean and cowpea.

The system involved interplanting maize/cassava/soybean in the major season and then interplanting cowpea into the cassava in the minor season. The results indicated that cassava tuber yield was significantly higher when soybean was planted simultaneously with maize than when it was sown two weeks after maize. It is possible that soybean growth was suppressed by maize when sown two weeks after the latter; this probably reduced the ability of soybean to fix atmospheric N, thereby forcing it to obtain its N requirements from external sources. The results also showed that yields of two varieties of cassava undersown with cowpea during the minor season were higher than those grown in plots not planted with cowpea. The difference is probably attributable, in part, to the mulching effect of cowpea, both as live and dead mulch; also some of the N fixed by cowpea was probably utilized by cassava.

Technology intervention through alley farming

Alley farming involves growing food crops between hedgerows of leguminous woody shrubs and tree species, which are pruned periodically to prevent shading of the food crops and to provide mulch, organic matter and nutrients to companion food crops. Farmers with small ruminants could benefit from supplementary browsing of cut hedgerows. The acclaimed advantages include a low input technology that fits into traditional multicropping systems; erosion and weed control; and the provision of mulch, fuel wood, fodder, and stakes for yams and small construction.

A trial was conducted to determine the effects of two multi-purpose leguminous species (*Flemingia congesta* and *Leucaena leucocephala*), as mulching materials, on growth and yield of plantain. The results indicated that *Flemingia sp*. produced higher biomass and also decomposed more slowly when compared to *Leucaena* sp. Thus, soil moisture content was higher and soil temperature lower under *Flemingia*. Growth and yield of plantain were therefore higher in *Flemingia*-mulched plots than in *Leucaena*-mulched plots (Table 1). It has been reported that 224-274 kg/ha of symbiotically fixed N were harvested in prunings of *Leucaena*_after six months (Giller and Wilson, 1991). At least similar amount of N could be harvested in prunnings of *Flemingia*, given the performance of this legume relative to *Leucaena* in the present trial. In addition, *Flemingia* prunnings suppressed the build-up of parasitic nematodes populations, while *Leucaena* acted as a good host for these parasitic nematodes.

Table 1. Effect of mulching treatment on and yield components of plantain at Fumesua in 1993/1994.

Treatment	Plantain yield and yield components			
	Number of hands/bunch	Number of fingers/bunch	Finger weight (g)	Yield (t/ha)
Flemingia	6	26	180.2	4.7
Leucaena	7	28	116.2	3.3
No mulch	6	26	135.1	3.5
LSD (5%)	1.0	4.0	36.6	0.8

Application of the above findings would help to regenerate fertility of a maize/cassava/plantain/cowpea system to promote food security and sustainability. For the small farmer, addition of expensive and often scarce external inputs like fertilizer to reduce resource limitation does not appear advantageous. Emphasis should be placed on yield stabilizing technologies such as the use of varieties tolerant to the most common biotic and abiotic stresses, as well as the adoption of management practices that minimize the adverse effects of periodic moisture deficits and reduce dependence on inorganic fertilizers. For example, partial budget analysis has indicated that intercropping soybeans with cassava generated 52% or 62% higher income than that generated from planting soybean or cassava, respectively, as sole crops (Ennin-Kwabiah *et al.*, 1993).

The maize/cowpea intercrop

A study was conducted to determine the benefits of the maize/cowpea system. The 1987 results showed that cowpea yields were increased when it was intercropped with maize. Plots with double rows of cowpea consistently outyielded those with alternate (single) rows or monocrop cowpea, particularly when maize planting was delayed for 10 days (Table 2). LER values for all intercrop combinations were greater than 1, suggesting a more efficient use of land when maize was intercropped with cowpea than when the crops were grown as pure crops. Double rows of cowpea arrangement gave the highest yields of both crops, the highest LER, and the highest net benefit values.

In 1988, all the LER values for the intercrop combinations were again greater than 1 (Table 3). Aburotia with Soronko gave the highest LER. The Dobidi + Soronko and Aburotia + Soronko combinations produced the highest net benefits (Table 3). All varietal combinations involving IT82D-716 had negative marginal rates of return (MRR), indicating that this variety is not suitable for intercropping. Partial budget analysis of 1988 results indicated that Dobidi + Soronko or Aburotia + Soronko combinations produced high net benefits and attractive MRR.

Table 2. Grain yield (kg/ha) of intercropped maize and cowpea as influenced by variety and spatial arrangement in 1987 at Fumesua, major season.

Factors	Grain yield (kg/ha)	
Cowpea variety +		
1) Asontem	966	
2) Soronko	1205	
Maize variety		
1) Dobidi	3428	
2) Aburotia	1783	
Spatial arrangement	Cowpea	Maize
1) Alternate rows of maize and cowpea, 80 cm apart.	789	2,833
2) Double rows of cowpea between two rows of maize, 80 cm apart.	1,215	2,875
3) Two rows cowpea between two rows maize 120 cm apart.	1,253	1,839
Overall mean	1,086	2,516
CV (%)	21.16	

+ Asontem = Semi-erect, light red 60-65 day extra early variety
Soronko = Semi-erect, brown 70-80 day medium maturing variety.

Table 3. Maize and cowpea grain yield, LER and Net benefits as affected by intercropping and varietal combination, Fumesua, 1988, major season.

Varietal combination	Grain yield (kg/ha)			Net benefit (cedis/ha)
	Maize	Cowpea		
Dobidi monocrop	3611	89,511		
Aburotia monocrop	2920	65,970		
Soronko monocrop	1793	93,200		
IT82D-716 monocrop	1983	110,176		
Dobidi + Soronko	2818	1108	1.40	102,803
Aburotia + Soronko	2312	1232	1.53	102,262
Dobidi + IT82D-716	2991	739	1.20	85.744
Aburotia + IT82D-716	1870	800	1.04	52,282
Mean	2498	933		
LSD (.05)	ns	133.9		
CV (%)	45.6	13.5		

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Cropping Systems and Long-Term Soil Fertility Management for Sustainable Agriculture in Northern Ghana

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Abstract

The high population growth (about 4% per annum) in the northern Ghana coupled with lack of access to land, called for a shift from traditional bush fallow system to permanent agriculture. This has also put immense pressure on the natural resource base with a consequent degradation of the limited arable land and, therefore, a reduction in agricultural potential. Recent studies on cropping systems to improve the soil productivity in this area have provided some promising solutions. Intercropped maize and cassava yielded 1.5 tons/ha and 2.0 tons/ha, respectively, more than the sole crops. Groundnuts and cowpea were considered excellent preceding crops for maize as maize yielded 3 tons/ha more when it followed any of them than when it followed maize or sorghum in a rotation. The N applied to cereals in a cereal/legume based intercrop and the activities of the N-fixing bacteria in the legumes enhanced the availability of N in the soil and its subsequent uptake by the succeeding crops.

Résumé

La forte croissance démographique dans la savane Nord du Ghana (environ 4% par an) associée aux difficultés d'accès à la terre a entraîné le passage du système traditionnel de jachère à l'agriculture permanente. Ce système a cependant exercé une pression considérable sur la base de ressources naturelles, ce qui a provoqué une sérieuse dégradation des terres arables limitées et de ce fait une réduction du potentiel agricole de la région. Les études récemment réalisées sur les systèmes culturaux en vue d'améliorer la productivité des sols dans cette région ont produit des résultats prometteurs. Les rendements du maïs et du manioc se sont révélés respectivement supérieurs de 1,5 to et 2 t dans des conditions d'association de cultures par rapport aux rendements obtenus en culture pure. L'arachide et le niébé ont été considérés comme d'excellents précédents culturaux pour le maïs dans la mesure où le rendement du maïs après ces cultures était de 3 tonnes supérieur au rendement du maïs succédant à lui-même dans une rotation. L'application de N sur les céréales dans une association céréale/légumineuse et l'activité des bactéries fixatrices d'azote des légumineuses rendaient N du sol plus assimilable et favorisaient son absorption subséquente par les cultures suivantes. Par ailleurs, la communication présente d'autres résultats et leur impact au niveau paysan ainsi que des suggestions de recherche qui renforceront notre aptitude à gérer le sol dans différents systèmes de culture afin de parvenir à une agriculture durable dans la Savane du Nord.

Introduction

The inherent capacity of a soil to supply nutrients to plants in adequate amounts and suitable proportions can be lost through continuous cropping. This capacity can be maintained or restored by the incorporation of organic or inorganic fertilizers.

The savanna soils are generally poor in organic matter and nutrients and are especially susceptible to deterioration caused by undesirable cultural practices. In the past, peasant farmers employed methods such as bush fallow and fertilizer application to remedy this situation for sustainable food production. However, due to increasing population pressure on land, along with changing socio-economic structures, the bush fallow period is greatly shortened, or has disappeared, while fertilizers are scarce and expensive.

In order to make food available to the increasing population, the use of permanent cultivation has become more and more the prevailing practice. Research activities have been concentrated on the agronomic practices that favour productive and stable farming systems without making undue demands for expensive and scarce external inputs. The data generated by studies on cropping systems and long term fertility management for sustainable agriculture in northern Ghana have not been reviewed either in part or in full. The objective of this paper is to summarize the results of past research in these areas in order to guide future research and development initiatives.

Mixed Cropping

Mixed cropping or intercropping is widely practised among small-scale farmers in the savanna ecological zone of West Africa, including Ghana. The adoption of this system by peasant farmers is determined mostly by their desire to avoid risks and stabilize incomes (Abalu, 1977). Most of the research on mixed cropping has been done to determine suitable components of the mixtures, elucidate residual effect of the legumes in the system on the succeeding crops, and assess the effects of application of fertilizers in the intercrop system.

SARI (1982) reported that increasing the population of maize in maize/pigeon pea intercrop in the savanna zone of Ghana had no effect on the yield of pigeon pea. However, increasing the proportion of pigeon pea up to half in the system reduced maize yield significantly (Table 1); the reduction in maize yield suggests a stronger interspecific competition for resources by the pigeon pea than by maize.

Table 1. The effect of maize/pigeon pea intercropping on the yields of maize and pigeon pea, 1982.

Treatments	Plant population		Grain yields	
	Maize (1000/ha)	Pigeon pea (1000/ha)	Maize (kg/ha)	Pigeon pea (kg/ha)
Sole pigeon pea (75 cm)	-	30	-	195
Sole pigeon pea (105 cm)	-	15	-	171
Sole maize (75 cm)	32	-	1,546	-
Maize/pigeon pea 1:1	20	17	893	176
Maize/pigeon pea 3:1	26	9	1,887	226
Maize/pigeon pea 6:1	29	6	1,375	82
Mean	27	15	1,424	170
SE+			175	37.3
LSD (0.05)			540	NS
CV (%)			25	44

Source: 1982/83 SARI Annual Report.

Grain yields of maize and cowpea in an intercrop situation are significantly higher per available area of land than their sole crop yields (SARI, 1984). According to Schmidt and Frey (1988), intercropping maize with groundnuts appears not to have any advantage over their respective sole crops yields. Also the application of N to the system significantly increased the yield of maize but not that of groundnut. They suggested that the response of maize to N application indicated low nitrogen status of the soil while the non-response of groundnut was probably related to its capacity to fix atmospheric nitrogen.

Crop Rotation

For optimal results, it is essential to determine the most favourable combination of crop successions in a rotation. Schmidt and Frey (1989) investigated the effects of various preceding crops and N fertilization on cereal production and found that maize was highly responsive. Thus, maize grain yields were depressed when maize was grown after maize or sorghum, probably because these cereals have the same nutrient requirements and feed from the same zone of the soil. However, grain yield of maize grown with or without N application after a preceding crop of groundnut increased significantly (compared to yield of maize preceded by maize or sorghum), suggesting that groundnut is a suitable preceding crop to maize. Also the nitrogen fertilization x preceding crop interaction had significant effect on maize grain yield but not on stover yield.

Maize and cassava yields can be increased several times when these crops are intercropped and rotated with groundnuts, as compared to their sole crops. For example, SARI (1988) reported that intercropped maize and cassava grown after a preceding crop of groundnut yielded about 1.5 t/ha and 2.0 t/ha, respectively, higher than their sole crops.

Grain yields of cereals after yam that received N fertilization were as high as those of cereals after groundnut, indicating that, under these conditions, yam compares favourably with groundnut as a preceding crop to cereals (SARI, 1993).

In a recent rotation experiment to test groundnut, cassava, soyabean, cowpea and sorghum as preceding crops for maize, SARI (1994) found that groundnut, cassava and soybeans were suitable preceding crops for maize (Table 2). Thus, yields of maize grown after groundnut, cassava, and soyabean were 3.87, 3.61 and 3.56 t/ha, respectively, compared to 1.82 t/ha produced by maize preceded by sorghum.

Table 2. Effect of intercropping and crop rotation on yield of various crops at Nyankpala, 1994.

Preceding crop to maize/ cropping partners to maize	Maize grain yields (t/ha)			Yields of cropping			Total LER
	Sole	Intercropped	LER	Sole	Intercropped	LER	
Groundnuts	3.87	1.38	0.36	1.33	0.62	0.50	0.86
Cassava	3.61	0.83	0.23	2.10	1.46	0.69	0.92
Soybeans	3.56	0.42	0.12	0.75	0.39	0.52	0.64
Cowpea	2.82	0,.52	0.18	1.39	0.84	0.60	0.78
Sorghum	1.82	1.12	0.61	0.85	0.52	0.61	1.22

Source: 1994 Annual Report of Savanna Agricultural Research Institute, Nyankpala.

Use of Cover Crops

There are few reports of soil studies involving cover crops in the savanna zone of Ghana. The use of cover crops in maintenance and enhancement of soil fertility is relatively a new concept and not universally recognised (Bruce *et al.*, 1991). Cover crops are said to protect the soil from wind and water erosion, minimize nutrient loss through leaching, and serve as green manure.

Cover crops such as *Mucuna utilis*, *Callopogonium mucuniodes*, *Pueraria phaseloides*, *Canavalia ensiformis* and *Macroptilium atropurens* (sirato) were found to be well adapted to the savanna zone of Ghana. Currently they are being studied both on-station and on-farm for their role in recovery and maintenance of soil fertility. To date, *Callopogonium mucunoides* has shown promising results (SARI 1993). For example, Dogbe and Nyamekye (1994) recorded better soil properties (e.g., higher soil N, organic matter and cation exchange capacity) of soil under *C. mucunoides* compared with soil from farmer's field without a cover crop. Rice grain yields were also significantly higher in the *C. mucunoides* fallow, with or without applied N, than under bush fallow or continuous cropping. These results and those of Rudat and Frey (1994) suggest that establishing a cover crop like *Callopogonium* at the latter part of the rainy season before the next cropping season, sustains crop production by the resource-poor farmer.

Alley Cropping

Alley cropping is an innovative food production technology by which food crops are grown in between rows of trees or shrubs (hedge rows), preferably legumes. According to Kang *et al.* (1985) alley cropping has major potentials for maintaining soil fertility under continuous cropping. The forage pruned from the fast growing trees or shrubs growing with food crops provide green manure and mulch to the associated food crops and contribute significantly to nutrient recycling, nitrogen supply, soil conservation, partial weed suppression and maintenance of soil productivity. In addition, the trees provide fuel wood, staking material for yam, and feed for livestock. Significantly higher maize and cassava yields were also obtained from alleys than from the check plots without hedge rows (Kang and Duguma, 1985). Large savings of nitrogen fertilizer were also reported by Ngambeki (1985) when maize was grown in alleys with *Leucaena*.

Thirteen accessions of *Gliricidia sepium* were evaluated for their potential in alley cropping in the savanna zone of Ghana (Naab and Nyamekye, 1990). At 12 months after planting, HYB produced significantly more mulch than any of the other accessions. Its regrowth vigour after pruning was also highest as it consistently out-grew the others (Table 3). Also, Rudat and Frey (1990) reported increase in yield of maize in alleys with *Gliricidia* and *Leucaena* where the forage of these trees was constantly pruned and incorporated in the soil several times before cropping periods.

Work is also in progress to screen five species of trees [*Parkia biglobosa* (dawadawa), *Vitellaria paradoxca* (sheanut), *Gliricidia sepium, Leucaena leucocaephala*, and *Acacia albida*] for their ability to improve soil fertility and to increase yields of cereals such as maize and sorghum. The results so far indicate that fast growing trees, such as *Gliricidia*, where a lot of biomass has been pruned onto the soil gave higher yields of maize and sorghum than slower growing trees (Tables 4 and 5). Lower yields of the crops were obtained where the trees could not be pruned due to slow growth of the trees (Rudat and Frey, 1994). This has been attributed to competition for water, sunlight, and minerals resources between the crops and the slow growing trees.

Table 3. Fresh mulch yields (kg/ha) from 4 harvests of *Gliricidia sepium*, 1987-1988.

Accession of *G. sepium*		Fresh mulch yield (kg/ha) on:			
		June '87	April '88	July '88	Oct. '88
ILG	50	18.23	7.63	14.40	15.41
	56	11.30	7.80	15.46	11.86
	62	15.88	5.79	13.40	12.56
	64	13.58	6.79	15.86	15.63
	65	11.09	5.44	12.99	10.29
	66	11.46	5.49	15.04	14.87
	68	12.13	5.15	12.24	12.12
	69	10.07	7.47	16.79	16.01
	70	12.11	6.73	14.36	13.98
	71	8.56	5.81	19.31	10.28
	72	6.34	4.01	10.41	8.13
HYB		22.90	8.02	19.43	18.03
LSD (5%)		5.58	-	5.19	4.07
CV (%)		26.56	-	20.27	18.32

Source: Naab and Nyamekye (1990)

Table 4. Maize grain yield (kg/ha) under agroforestry system at SARI, 1992.

N fertilizer rate (kg/ha)	Acacia	Leucaena	Parkia	Gliricidia	Vilellaria	Check	Mean
0	1397	1367	1533	2240	1227	1987	1625
40	2250	1960	1937	2623	1887	2860	2253
80	2203	2643	2333	2630	1833	3180	2471
Avg.	1950	1990	1935	2498	1649	2676	2116

CV (%) Tree = 33., 6; N - level = 15.7

LSD (5%): Species = 738; N x Species = 867; N - levels = 229.

Table 5. Sorghum grain yield (kg/ha) under agroforestry system SARI, 1992.

N fertilizer rate (kg/ha)	Acacia	Leucaena	Parkia	Gliricidia	Vilellaria	Check	Mean
0	197	117	160	240	167	207	164
40	223	130	167	273	247	247	198
80	300	207	260	293	290	277	254

CV (%) Tree = 26.6; N - level = 21.7

LSD(5%): Species = 57; N x Species = 83; N - level = 30.

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Agriculture Durable à Dominante Coton : Caractéristiques, Contraintes et Voies d'Amélioration pour une Agriculture Durable dans la Zone de Savane Humide de Côte d'Ivoire

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Résumé

Dès le début des années 1960, le gouvernement ivoirien a reconnu le besoin de diversifier la production agricole. Ceci afin d'une part d'éviter une dépendance excessive par rapport aux deux principales cultures d'exportation que sont le café et le cacao, et assurer d'autre part au pays, une plus grande sécurité alimentaire. Par ailleurs, cette diversification permettrait de lutter contre la disparité économique entre la zone forestière et celle des savanes par l'introduction du coton.

Depuis lors cette politique volontariste de développement de la culture cotonnière dans la zone des savanes a eu un impact considérable. A juste titre, l'on parle aujourd'hui d'un système de cultures à base de coton où le cotonnier joue le rôle de 'culture-motrice' dans les savanes humides de la Côte d'Ivoire.

Son impact sur les cultures vivrières avec lesquelles il est associé est indéniable, car il est la seule spéculation annuelle véritablement intensifiée en terme d'utilisation de facteurs de production (engrais, insecticides et herbicides). Face à la réduction du cours international de la fibre et à la récente dévaluation du franc CFA, un accent particulier doit être mis sur cette complémentarité entre le cotonnier et les cultures vivrières, voire d'autres cultures de rente adaptées à la zone humide des savanes. Les différentes contraintes à cette production agricole intégrée doivent être levées pour un meilleur devenir des populations.

Abstract

Ever since the early sixties, the government of Côte d'Ivoire recognized the need for diversifying agricultural production in order to avoid excessive dependence on the two major export crops, namely coffee and cocoa, on the one hand and to ensure greater food security for the country on the other hand. Furthermore, the economic disparity between the forest zone and the savanas could be reduced through the introduction of cotton production.

Since then the impact of this voluntary policy of cotton crop development in the savana zone has been considerable.

The impact of cotton on the companion crops is obvious since it is the only annual crop being grown quite intensively with the use of fertilizers, insecticides and herbicides. In view of the decrease in the international trade of the fiber and of the recent devaluation of the CFA franc, special emphasis should be put on the complementarity between cotton and food crops or even other cash crops adapted to the humid savana

zone. The various constraints to this integrated agricultural production system will need to be overcomed to benefit farmers.

Introduction

La culture du coton en Côte d'Ivoire date du début du siècle (Hau, 1988). A partir de 1962, elle connaîtra un essor grâce à une politique volontaire de soutien de la part du gouvernement qui vise à réduire les disparités régionales. Selon cette même volonté politique naîtra en 1974, la Compagnie Ivoirienne de Développement des Textiles (CIDT) dont la mission est d'assurer le développpement rural des savanes de la Côte-d'Ivoire.

L'évolution de la culture du cotonnier est intimement liée d'une part, aux progrès réalisés par la recherche agronomique et d'autre part, à l'encadrement efficace des agriculteurs par la société de développement. Spéculation longtemps secondaire conduite en association avec des cultures vivrières, le cotonnier est devenu progressivement la culture principale des zones de savanes.

Le système de production agricole est essentiellement fondé sur la culture itinérante et sur la régénération des sols par le biais de longues périodes de jachère naturelle. Actuellement, cette technique n'est plus soutenable pour plusieurs raisons parmi lesquelles l'on peut retenir :

- la saturation foncière de la zone cotonnière et l'augmentation de la densité dans la zone forestière où de nouvelles terres à défricher sont de plus en plus rares,
- le changement notable du ratio entre les populations rurale et urbaine (4 : 1 en 1960; 1:1 en 1995 et 0,6 : 1 en 2010)
- le déclin continu du prix des principaux produits agricoles d'exportation
- l'appauvrissement des ressources naturelles et la baisse de la productivité de la culture cotonnière et des cultures subséquentes.

Cette situation de crise du secteur agricole ivoirien, impose des changements drastiques aux systèmes culturaux, afin d'intensifier les pratiques culturales et de diversifier l'agriculture hors des cultures traditionnelles d'exportation pour une agriculture durable.

L'objectif de cet article consiste essentiellement à faire le point sur les caractéristiques agro-techniques, contraintes d'exploitation et possibles voies d'amélioration du système de cultures à base de coton dans la zone de savane humide en Côte d'Ivoire.

Caractéristiques Agro-techniques de la Culture Cotonnière en Côte d'Ivoire

1. Superficies emblavées

Le paysan a su intégrer le cotonnier dans son système de production, sans trop déséquilibrer les cultures vivrières qui occupent toujours une place importante (plus de 50%). Cela a permis aux paysans de s'assurer en plus d'une certaine garantie financière, une sécurité alimentaire (tableau 1).

De 1968 à 1994, le nombre des planteurs encadrés (tableau 2) par la CIDT a plus que doublé et est passé de 61 863 à 131 879 pour une superficie de 48 139 hectares en 1969 à près de 220 000 hectares en 1994. Ceci dénote de l'intérêt des agriculteurs qui tirent désormais l'essentiel de leur revenu et de leurs moyens de progrès de la culture cotonnière. Ainsi de 1989 à 1994, plus de 23 milliards ont été annuellement distribués aux planteurs, soit un revenu moyen d'environ 180 000 francs CFA par exploitant/ en (tableau 2).

Tableau 1. Superficies annuelles encadrées par culture (en % de la superficie totale exprimée en ha.)

Cultures	1989/90	1990/91	1991/92	1992/93
Coton %	47.5	48.0	45.1	48.3
Riz irriggué %	2.0	1.9	1.9	1.8
Riz pluvial %	16.0	16.6	16.7	15.4
Maïs %	22.9	21.2	23.0	21.1
Arachide %	11.4	12.2	13.3	13.3
Total CIDT (ha)	424 089	413 626	422 224	463 718

Tableau 2 . Evolution des caractéristiques de la production cotonnière et des revenus.

Caractéristiques de production.	1989/90	1990/91	1991/92	1992/93	1993/94
Planteurs encadrés	148 008	123 908	119 237	133 421	130 879
Superficie (ha)	201	198 516	190 473	224 078	219 425 258 343
Productions coton (tonnes)	390	261 139	193 768	238 784	1 178
Rendement moyen (kg/ha)	241 700	1 316	1 017	1 066	26.675
Revenus (milliards de FCFA)	1 200	24.804	17.308	21.325	
- aux paysans					1 085
- ristournes des coopératives	25.468	-	0.814	1 003	
- primes de gestion intrants	-	-	-	0.743	0 075 203.814
- revenu par planteur	-	200.185	145.167	159.751	
(FCFA)	183.578				

2. Rendements de la culture cotonnière

Le rendement moyen en coton graine a évolué de façon linéaire ces 30 dernières années, avec un gain annuel de plus de 20 kg, imputables à la fois au progrès génétique, à la définition d'itinéraires techniques appropriés et à une protection phytosanitaire poussée. Par contre, l'on assiste à une baisse du rendement moyen pendant ces dernières années (tableau 2), alors qu'il avait atteint 1 410 kg/ha en 1987-1988 (rapport annuel de la CIDT, Campagne 87/88).

3. Mécanisation de la zone des savanes

Toutes spéculations confondues, plus de 85 % des surfaces sont conduites en culture attelée dans le Nord du pays (tableaux 3 & 4). Cette proportion est plus faible dans le Centre qui se caractérise par l'absence de tradition d'élevage et un taux de mortalité des boeufs relativement élevé.

Tableau 3 . Mode de préparation du sol de 1989 à 1994.

Caractéristiques de production	1989/90	1990/91	1991/92	1992/93	1993/94
Planteurs encadrés :	148 008	123 908	119 237	133.421	130 879
	79.0	77.2	75.3	76.2	74.6
- culture manuelle %	20.20	21.7	24.0	23.5	24.9
- culture attelée %	0.5	0.3	0.4	0.2	0.3
- motorisation intermédiaire					
- motorisation conventionnelle	0.1	0.8	0.3	-	0.2

Tableau 4. Taux de mécanisation de 1990 à 1993 (en % des superficies par culture).

Surface mécanisée par culture en % de la surface totale	1989/90	1990/91	1991/92	1992/93
Coton	40.7	45.1	48.5	45.5
Riz irrigué	9.1	5.6	2.7	0.2
Riz pluvial	40.4	40.8	43.1	43.6
Maïs	37.2	41.7	44.4	46.3
Arachide	30.2	34.2	37.6	39.4
En % du total CIDT	37.8	41.6	44.4	43.9
Total CIDT (en ha)	424 089	413 626	422 224	463 718

4. Fertilisation des cultures

L'utilisation de la fumure minérale (NPK) varie selon les cultures. Elle concerne plus de 86 % des surfaces cultivées en coton, 56 % pour le riz irrigué, 19 % pour le riz pluvial et 17.6 % pour le maïs (tableau 5). La fertilisation des cultures est plus importante et plus répandue au Nord (plus de 96 %) et à l'Ouest (65 %) qu'au Centre (30 %) où l'on observe plus de lenteur dans l'application des recommandations.

Tableau 5. Superficies fertilisées, en % des superficies par culture.

Cultures	1989/90	1990/91	1991/92	1992/93
Coton	97.0	80.0	88.0	81.5
Riz irrigué	87.0	48.8	42.6	44.3
Riz pluvial	24.0	18.8	16.2	16.1
Maïs	20.0	17.7	17.0	15.6
Arachide	0.0	0.0	0.0	0.0

5. Herbicidage des cultures

L'utilisation des herbicides varie également selon la culture et la région. Le taux est en augmentation et concerne environ 21 % des superficies totales (tableau 6).

Tableau 6 . Surfaces herbicidées (en % des superficies par Culture).

Cultures	1989/90	1990/91	1991/92	1992/93
Coton	37.0	35.2	32.0	30.7
Riz irrigué	14.0	12.0	14.0	2.6
Riz pluvial	36.0	34.0	29.6	30.0
Maïs	10.0	21.7	29.5	11.0
Arachide	5.0	5.4	8.0	5.7

6. Protection phytosanitaire

La protection phytosanitaire est poussée sur la culture cotonnière, contrairement aux cultures vivrières qui n'en comportent pratiquement pas. Au moins six (6) traitements-insecticide sont recommandés sur le cotonnier à compter du 45ème jour après le semis.

7. Effets bénéfiques de la culture cotonnière en zone de savanes

L'impact de la culture cotonnière sur la zone des savanes est considérable. Les actions conjuguées de la recherche et du développement ont fait du cotonnier la culture motrice de cette zone, permettant le développement des cultures vivrières et l'amélioration globale du cadre de vie des paysans. Ceci se traduit notamment par :

- la structuration du milieu rural qui compte aujourd'hui 640 Groupements à vocation coopérative (G.V.C) de base, 25 unions locales et une union faîtière de troisième niveau, l'URECOS-CI (Union Régional des Entreprises Coopératives des Savanes de Côte-d'Ivoire) qui assure déjà la collecte primaire de 100 % coton-graine,
- la modernisation des exploitations agricoles qui se traduit par 50 % de culture attelée, 25 % de motorisation des superficies emblavées,
- de même, on peut affirmer que la culture cotonnière est la seule spéculation annuelle

véritablement intensifiée en terme d'utilisation des facteurs de production (engrais, insecticides et herbicides),
- la mise en oeuvre d'un tissu industriel décentralisé qui comprend 10 unités d'égrainage sur l'ensemble des zones de savanes,
- la création d'infrastructures économiques et sociales financées en partie par les ristournes du coton,
- l'incidence significative de la filière coton sur les cultures vivrières, car dans le cadre de l'assolement, à un hectare de coton sont associés deux hectares de cultures vivrières.

Contraintes d'exploitation du système à base de coton

Au plan de la sécurité alimentaire, le système est sécurisant tout au moins pour le paysan, même si cette production vivrière ne lui garantit pas un revenu monétaire régulier et important. En effet, les cultures vivrières améliorent sensiblement leurs rendements en bénéficiant de leur association avec le coton dont la culture est plus intensive.

Au plan financier par contre, le revenu monétaire du paysan qui devrait croître, a connu au contraire une baisse sensible ces dernières années, à cause de la crise économique. En plus, la filière coton est malade des cours mondiaux qui ont un niveau bas malgré la récente dévaluation du franc CFA qui a simultanément contribué à l'augmentation des coûts de production, car notre pays est surtout importateur d'intrants agricoles.

Ce système se caractérise aussi par la pratique de la monoculture du cotonnier. En effet, le paysan réserve ces bonnes terres à cette culture de rente, ce qui entraîne à terme une baisse de la productivité des sols. En outre l'utilisation répétée des herbicides coton qui sont généralement des graminicides, induit une inversion de la flore et l'apparition d'espèces difficiles à maîtriser. C'est le cas avec Euphorbia hétérophylla et à un degré moindre Commelina benghalensus, qui amènent les paysans à abandonner leurs parcelles, alors qu'une rotation permettrait de résoudre le problème.

Le système de culture à base coton a souvent favorisé la dégradation des sols. La baisse du rendement moyen qui est passé de 1 413 kg/ha en 1987/88 à 1 066 kg/ha en 1992/93 s'explique par plusieurs facteurs, l'utilisation des formes d'engrais acidifiant et un bilan minéral largement déficitaire. Cette dégradation est accentuée par le saupoudrage de l'engrais-coton sur les spéculations de l'exploitation.

La réduction du nombre de traitements-insecticide est une pratique courante dans les conditions de crise accentuée par la dévaluation du franc CFA. Cette stratégie de désintensification est suicidaire dans le long terme car, le producteur se trouve pris dans un cercle vicieux de faible utilisation d'intrants, diminution de rentabilité, faible génération de revenue et d'incapacité d'auto-financement qui mène à la disparition de son patrimoine de ressources initiales.

Afin de lever ces différentes contraintes de dégradation des sols et de mauvaise maîtrise de l'enherbement, les paysans pratiquent la culture itinérante dans les régions où des terres sont encore disponibles ou bien restent sur leurs terres en assistant impuissant à la baisse de sa productivité.

Le système de culture à base coton présente néanmoins certains avantages tels que l'acquisition d'une plus grande technicité par le paysan, qui lui assure une plus grande sécurité alimentaire, et un revenu monétaire acceptable. Cependant, ce système présente des insuffisances au plan de sa durabilité.

Approche de Solutions pour une Productivité Durable du Système de Cultures à Base de Coton

Plusieurs voies d'amélioration existent : ce sont notamment, la réduction des coûts de production par l'utilisation d'engrais organiques (poudrette de parc, fumier, restitution des résidus de récolte, etc.) et la régionalisation de l'utilisation des intrants qui en un mot se traduit par la recherche d'une performance accrue et la diversification dans les spéculations.

1. Recherche de performance

L'écart substantiel qui existe entre les rendements actuels et potentiels pour la plupart des spéculations témoigne des possibilités considérables d'expansion des exportations agricoles et de renforcement de la sécurité alimentaire. Le rendement moyen du coton est d'environ 1 200 kg/ha en Côte d'Ivoire, pour un potentiel de 4 000 kg/ha pour les variétés vulgarisées.

Cependant il est bon de préciser que certains planteurs atteignent entre 2 500 et 3 000 kg/ha rien qu'en respectant les itinéraires techniques établis par les services de recherche/développement. Ainsi, le paysan pourrait accroître ses revenus grâce à la mise en place d'un système rationnel de cultures.

Pour remédier à cette situation, les solutions résideraient dans l'élaboration de nouveaux systèmes culturaux adaptés aux conditions de travail du paysan, la fourniture de conseils de vulgarisation sur les intrants et l'examen des questions foncières en vue de sécuriser l'exploitant et l'inciter à investir davantage sur ses terres à long terme.

Concernant les systèmes culturaux, il convient de souligner qu'un programme de recherche-système fondé sur des expérimentations complexes de longue durée pour la fixation de l'agriculture, a été lancée en 1986 par l'IDESSA, sur des points d'expérimentation système (P.E.S.) en zone dense de Korhogo. Les résultats obtenus sur les PES feront l'objet d'une expérimentation supplémentaire sur les sites d'adaptation de la recherche système (SARS) avant d'être vulgarisés.

En attendant de nouvelles méthodes culturales, il faudra nécessairement avoir recours aux intrants manufacturés (herbicides, engrais, et perticides) et aux autres technologies d'accompagnement. En raison de la forte baisse constatée sur les revenus ces dernières années, la consommation des intrants est tombée de manière drastique bien que le coût de ceux-ci et du matériel agricole soit demeuré plus ou moins stable.

Le paysan pourrait procéder par une séquence de petites améliorations pour rehausser progressivement son niveau de gestion et de compte ; cela lui permettra ainsi d'atteindre un mode de développement durable fondé sur une augmentation de la rentabilité, le maintien de la fertilité des sols et la stabilisation de l'agriculture.

2. Diversification des spéculations

Les pays d'Afrique Occidentale en général ont un avantage comparatif sur les marchés mondiaux pour bon nombre de produits tropicaux (U S A I D, 1990 ; Koester et al., 1990). Ceci est particulièrement vrai pour les produits d'exportation traditionnels et ceux non traditionnels dont le marché est en forte expansion (fruits frais, légumes frais).

Les cultures vivrières traditionnelles (tubercules, aubergines, poivrons, haricots vert...) représentent également une opportunité de diversification tant pour le marché intérieur que pour le marché international.

La zone cotonnière de Côte d'Ivoire regorge de potentialité pour promouvoir ces différents produits grâce aux atouts suivants :

- un climat propice à une large gamme de produits tropicaux ;
- des infrastructures efficaces facilitent les échanges avec les pays étrangers ;
- la proximité relative du vaste marché européen en expansion ;
- les liens historiques de la Côte d'Ivoire avec l'Europe ;
- l'existence d'une base agro-industrielle capable d'assurer le conditionnement et la première transformation des produits.

Jusqu'à présent, les efforts de diversification ont eu des résultats mitigés et leur portée est demeurée modeste en regard du potentiel de production et de l'avantage comparatif de la Côte d'Ivoire.

La plage de progrès à réaliser est encore plus grande sur les cultures vivrières que le cotonnier qui est la culture de rente de la région des savanes et par conséquent pratiqué de façon plus intensive.

Par le fait de la croissance démographique, le développement de l'urbanisation et de la dévaluation du f CFA, la demande de produits agricoles est forte sur le marché intérieur et sous-régional. Cela représente à la fois une opportunité d'amélioration des revenus agricoles et un défi d'augmentation de la productivité des cultures vivrières pour une croissance équilibrée de l'agriculture à long terme. Si ce défi n'est pas relevé, les importations de produits alimentaires influenceront négativement la balance des paiements.

En zone de savanes, on pourrait notamment envisager deux voies possibles de diversification:

D'une part, les cultures non-traditionnelles d'exportation, notamment les fruits frais (mangues, limes, goyaves, etc.), les légumes frais de contre-saison (aubergines, poivrons, melons, haricots verts, les 'feuilles', etc.) et les produits divers (noix d'acajou avec la réouverture de l'unité de transformation de Korhogo, la sériciculture, l'apiculture, l'élevage, etc.) et d'autre part, les cultures vivrières traditionnelles que sont les tubercules et une grande diversité de légumes (gombo, courgette, tomates, oignons, épinards, piments, feuilles diverses et tous les autres condiments d'assaisonnement.

Conclusion

L'intégration du cotonnier dans le système de culture en région de savane a eu une incidence significative tant au niveau des habitudes culturales, qu'au niveau des conditions socio-économiques.

Cependant ce système à base coton n'a véritablement pas favorisé une agriculture durable assurant la régularité des rendements, la fixation des exploitations et la sauvegarde de l'environnement. En plus, la filière coton n'a pas été épargnée par la crise économique persistante de ces dernières années.

Les solutions pour l'équilibre de la filière se situent à plusieurs niveaux dont notamment, la recherche de la performance par un meilleur suivi des itinéraires techniques préconisés en vue d'une intensification véritable des exploitations, aussi bien pour le coton que pour les cultures vivrières qui lui sont associées. Ce résultat ne peut être atteint que par un renforcement de l'encadrement par la structure de développement. Dans ce contexte, la recherche, artisan non négligeable du progrès en zone de savane, est également interpellée pour la conception de nouveaux systèmes culturaux.

Enfin, la zone cotonnière de la Côte d'Ivoire avec ses potentialités agronomiques et pastorales énormes, gagnerait à diversifier ses produits pour une agriculture durable dans l'intérêt du paysan et de la nation ivoirienne tout entière.

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Studies on Mucuna (*Mucuna pruriens* var *utilis*) in Ghana.

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Abstract

Land pressure has forced farmers in the humid tropics to intensify land use, resulting in declining yields, weed invasion and soil erosion. Mucuna (*Mucuna pruriens* var *utilis*) has traditionally been grown for food by peasant farmers in Ghana. Experiments were conducted in 1992 and 1993 to determine the effectiveness of mucuna as a cover crop in controlling weeds in maize in the transition zone of Ghana. Informal surveys were also conducted during this period to determine the popularity of mucuna as a food crop and the methods used in preparing food with mucuna in the country. Results of the experiment showed that maize yield may be significantly reduced if mucuna is simultaneously intercropped with it, but yields may not be affected if mucuna is planted at 45 days after maize. When left as fallow for 1 year, mucuna, established either as intercrop with maize or as monocrop, produced large quantities of biomass which effectively controlled spear grass. Maize following mucuna, without fertilizer-N, yielded 4176 kg/ha compared to 1167 kg/ha when maize followed maize. Results of the survey showed that mucuna is a popular food crop among the people in the forest zone of Ghana.

Résumé

La pression foncière a obligé les paysans des zones tropicales humides à intensifier l'utilisation des terres, ce qui a entraîné la baisse des rendements, l'invasion des mauvaises herbes et l'érosion des sols. Mucuna (*Mucuna pruriens* var. *utilis*) est traditionnellement exploité par les paysans au Ghana comme culture vivrière depuis au moins le début de ce siècle. Différentes études ont été réalisées entre 1992 et 1994 sur l'utilisation de mucuna comme culture de couverture servant à lutter contre les mauvaises herbes dans la zone de transition du Ghana. Des enquêtes informelles ont été également menées durant cette période pour déterminer le caractère populaire de mucuna comme culture vivrière ainsi que les méthodes de préparation culinaire de mucuna dans le pays. Les résultats de l'une de ces études ont montré que le rendement du maïs pouvait être significativement réduit si mucuna était simultanément semé en association avec le maïs, mais que le rendement n'était pas affecté si mucuna était semé 45 jours après le maïs. Lorsqu'il était laissé en jachère pendant une année, mucuna semé comme culture associée avec le maïs ou comme culture pure produisait une grande quantité de biomasse qui éliminait efficacement le chiendent. L'humidité du sol sur les parcelles comportant mucuna était de 60 % supérieure à celle des parcelles sans mucuna. Le maïs suivant mucuna sans engrais N produisait 4176 kg/ha comparativement à 1912 kg/ha lorsque le maïs suivait le niébé. Le criblage de certaines variétés locales de mucuna a révélé que mucuna ayant des graines noires ou tachetées était plus vigoureux et plus agressif pour la lutte contre les mauvaises herbes par rapport à mucuna avec des

graines cendrées ou jaunes. Les détails de ces études et les résultats des enquêtes sur les utilisations traditionnelles de mucuna comme culture vivrière au Ghana sont présentés dans cette communication.

Introduction

Intensive land use, without adequate measures for soil conservation and weed control, has led to weed invasion and soil degradation in many areas of Africa. In the advanced nations, chemical fertilizers and herbicides play a major role in maintaining crop yields under intensive land use. With the removal of subsidies on farm inputs in many African countries, fertilizers and herbicides have become very expensive and/or unprofitable for the majority of farmers. The major task of researchers in the continent is to identify ways of maintaining crop yields under intensive land use with minimum use of purchased inputs. This task can be accomplished by the use of legume cover crops. Inclusion of cover crops in a cropping system confers several benefits, such as, weed control and soil conservation (Lal *et al*., 1991; Wilson *et al*., 1982; Versteed and Koudupon, 1990; Akobundu, and Okigbo, 1984). Despite these benefits, most cover crops do not provide direct benefit as food, an issue which is particularly important to the small-scale farmer. Mucuna (*Mucuna pruriens* var *utilis*) is one of the few legumes which produce edible seed (Ezueh, 1977) and have excellent attributes as cover crops (Hulugalle *et al.*, 1986; Buckles, 1995; Triomple, 1991). However, there is very limited information both on the agronomic uses of mucuna and its utilization as food. This paper discusses a study on mucuna as a cover crop and its utilization as food in Ghana.

Materials and Methods

Field trials

Researcher-managed experiments were conducted on farmers fields at Seko, Ejura, and Hiawoanwu (Hiawo) in the Ejura Sekyere Odumasi district of Ghana in 1992 and 1993. The study area falls within the forest-savanna transition ecological zone with a bimodal rainfall pattern. The length of growing period is 140 and 90 days in the major and minor seasons, respectively, while the mean annual rainfall is 900 mm in the minor season and 1200 mm in the major season. Land is moderately scarce and soil fertility is moderate to low. The most wide spread weeds are spear grass (*Imperata cylindrica*) and *Euphorbia* spp. Bush fire is very frequent in the harmattan period which lasts from December to February.

The objective of the experiment was to determine the effect of mucuna on maize yield. The experimental design was a randomized complete block replicated three times over six locations. All six sites were heavily infested with spear grass. Asontem and Abeleehi were the cowpea and maize varieties used, respectively, and the mucuna was a black seeded type obtained from Benin. Asontem is a semi-erect early cowpea and Abeleehi is a medium duration (105 days) maize variety. The treatments were as follows:

Tableau 1 : Crops grown under each of 7 treatments in 1992 and 1993

Major season (1992)	Minor season (1992)	Major season (1993)
T1. Maize	Cowpea	Maize with N
T2. Maize	Cowpea	Maize without N
T3. Cowpea	Cowpea	Maize without N
T4. Maize + Cowpea*	Cowpea	Maize without N
T5. Mucuna	Mucuna	Maize without N
T6. Maize + Mucuna Sim**	Mucuna	Maize without N
T7. Maize + Mucuna 45D***	Mucuna	Maize without N

* Maize + cowpea intercropped simultaneously
** Maize + mucuna intercropped simultaneously
*** Mucuna intercrop sown 45 days after planting maize.

Except otherwise stated, all cultural practices for maize and cowpea in the experiment were as recommended by the Crops Research Institute, Kumasi (GGDP, Maize and Cowpea Production Guide, 1992). The fields were prepared by ploughing once in the 1992 major season but by zero tillage technique, involving the application of 2 l/ha gramoxone, in subsequent seasons. Mucuna and maize were planted at a spacing of 80 x 40 cm in both cropping patterns, one row of mucuna alternating with one row of maize in the intercropping systems. Pruning of mucuna in the intercrops was done when necessary to prevent excessive maize climbing. Mucuna in the minor season was a fallow resulting from that planted in the major season. Cowpea was planted at a spacing of 50 x 20 cm in pure stands and at 40 x 20 cm in the intercrops, with two rows of cowpea between the maize rows. Cowpea was sown simultaneously with maize at Seko and at 7 days after the maize at the other locations. Mucuna seed was harvested at the end of the minor season.

In 1993, all plots were planted to maize (Abeleehi). All the plots received only phosphorus in the form of triple super phosphate at a rate of 75 kg of P_2O_5 per ha at planting, except the control, which received in addition 90 kg of N per ha. Nitrogen was split-applied in the form of urea at planting and at 5 weeks after planting. Spear grass control was scored in 1993 at maize tasselling using a scale of 1-5, where 1 represented complete control (or absence) of spear grass and 5 no control.

Survey to determine uses of mucuna

Data on traditional uses of mucuna in Ghana were collected through informal discussions with about 60 farmers in the forest and transition zones of the country from 1991 to 1994. The interviews were conducted in the villages of Goaso, Nkawie and Effiduasi (in the forest zone) and Seko, Ejura and Nkoranza (in the transition zone). During this period, the researchers made random stops at villages in various other parts of the country (particularly along the roads: Kumasi-Accra, Kumasi-Sunyani, Kumasi-Techiman, and Kumasi-Goaso) to interview farmers on the uses of mucuna.

Results and Discussion

Field trials

Three out of the six locations were lost before 1993 major season due to bush fires. The other sites were protected from bush fire with fire barrier (4-m wide ploughed strip of land around each field). Results from these three sites are presented below.

Maize grain yields in major season of 1992: In general, yields of maize were highest in the monocrops, but the monocrop yield was not significantly different from that of maize grown in mixture with mucuna, if the latter was sown at 45 days after maize (Table 2). However, simultaneous planting of maize with cowpea or mucuna resulted in significant reductions in maize yields, the decline being higher in the maize + cowpea intercropping system; the yield depression by cowpea was greatest at Seko. The low yields of maize in these cropping systems was attributed to severe competition which it suffered from the legumes. Maize, however, apparently escaped from this competition when mucuna was planted 45 days after it. At the initial stages, the growth of cowpea was faster than that of mucuna and this might have resulted in maize suffering greater competition from cowpea than from mucuna. Later, the pruning of mucuna vines reduced its competitive effect on the maize (mucuna planted simultaneously with maize or at 45 days after it was pruned four or two times, respectively).

The highest incidence of maize lodging (96 and 79%) were recorded in maize sown simultaneously with mucuna (Table 2). Though maize lodging was high in mucuna, this occurred at a late stage of maize growth, when pruning of mucuna vines had stopped. This might explain why lodging had small effect on yield. However, maize harvesting was more difficult in mucuna and this can increase harvest losses and reduce yields in commercial fields. On the other hand, lowest incidence of lodging occurred in pure crop maize or in maize intercropped with cowpea.

Table 2. Grain yield and percent lodging of maize as affected by cropping systems (1992 major season).

Cropping system	Grain yield (kg/ha) at:			Lodging (%) at:	
	Hiawo	Seko	Ejura	Seko	Ejura
Sole maize (mean)	2663	2474	4080	6	16
Maize + cowpea	1349	573	2812	4	13
Maize + mucuna (sim)	1997	1615	3130	96	79
Maize + mucuna (45D)	2429	2969	3996	69	29
CV (%)	11.1	37.4	14.9	50.8	43.2
LSD (0.05)	404	1245	835	30	22

Cowpea yields: Grain yields of cowpea in the 1992 major season were significantly higher at all three locations in the sole than in the intercropping systems, the mean yields being 1265 kg/ha and 727 kg/ha, respectively. However, in the 1992 minor season, the yield of cowpea was not affected by the preceding crop of the major season, except at Seko where yields were significantly reduced when cowpea followed cowpea (Table 3).

Table 3. Cowpea grain yield in 1992 minor season as affected by the preceding crop.

Preceding crop	Grain yield (kg/ha) at:		
	Hiawo	Ejura	Seko
Maize	817	833	732
Maize + cowpea intercrop	780	600	848
Sole cowpea	803	867	463
CV (%)	38.5	30.8	48.7
LSD (0.05)	ns	ns	555

Weed control and maize grain yields in 1993 major season: At the time of land preparation and maize planting, mucuna had died out completely, leaving a thick mat of mulch free of weeds. This allowed maize planting at Ejura and Seko without any land preparation. At Hiawo, where planting was delayed, there was weed regrowth on the mucuna plots but these were broad-leafed and the pressure was far less than on the plots without mucuna which had severe incidence of spear grass.

In general, maize without fertilizer-N yielded more on the plots with a history of mucuna than on those without. Without nitrogen fertilizer, mean grain yield was highest (4176 kg/ha) when sole mucuna was the first crop and lowest (1167 kg/ha) when maize followed maize (Table 4). Thus maize yielded more than thrice on the mucuna plots than on the maize plots. In the absence of fertilizer-N, maize yield was statistically the same in all the plots which had no history of mucuna. Application of fertilizer-N to plots without mucuna, however, resulted in maize yields comparable to, and in some cases higher than, that obtained in the mucuna plots. At all three locations, maize following maize with nitrogen yielded significantly higher (3446 kg/ha) than maize without nitrogen (1167 kg/ha) (Table 4). It can be inferred from the yield difference between the control and the treatments which had no history of mucuna that nitrogen was a limiting factor in soils of this experiment. Mucuna may, therefore, have contributed some nitrogen which resulted in the high yields of maize following it.

Table 4. Maize grain yield and weed control as affected by preceding crop, in the major season of 1993*.

Preceding crop	Speargrass score	Maize grain yield (kg/ha) at:			
		Hiawo	Ejura	Seko	Mean
Maize (control)	4.0	3667	3966	2704	3446
Maize	4.5	1048	1332	1121	1167
Cowpea	4.0	1572	2085	1979	1879
Maize + cowpea	3.5	1637	2417	1682	1912
Sole mucuna	2.0	4945	3956	3628	4176
Mucuna (sim)	2.5	3438	3253	2276	2989
Mucuna (45D)	1.5	2227	4244	2507	2993
CV %	19.4	32.5	23.3	35.0	29.5
LSD (0.05)	1.0	1417	1152	1310	739

* Preceding crop as used here implies the first crop (s) in rotation (see treatment list).

Mucuna (45D) - Mucuna intercropped at 45 days of sowing maize.

Mucuna (sim) - Maize + mucuna simultaneous intercrops.

Among the mucuna plots, yields of maize following sole mucuna were consistently the highest. Simultaneous intercrop of mucuna with maize had no maize yield advantage over that in which mucuna was sown 45 days after maize, except at Hiawoanwu.

Although the yield from the control treatment was comparable to those from the mucuna plots, the control plot had much more spear grass problems (score of 4) than any of the mucuna plots (Table 4). Spear grass was almost absent on the mucuna plots at the end of the experiments; in its place were broad-leafed weeds. The plots without mucuna, on the other hand, had severe pressure of spear grass, a weed which has forced some farmers in the study area to abandon their land.

Results of survey on uses of mucuna

Results of the interviews showed that many farmers in the forest and transition zones often grow mucuna for home consumption. Although mucuna is mainly grown for home use, minor quantities of the grain, mainly in the fresh state, are also sold in both villages and cities. About 50% of the respondents indicated that they consume mucuna regularly in soups and stew. The seeds of commonly grown mucuna are yellow, black, mottled and ash in colour. Most respondents aged up to 70 years claimed that their grandparents grew mucuna for food, suggesting that the crop has been used for food in Ghana for more than a century. None of the people interviewed indicated knowledge of any problems associated with mucuna consumption.

The results of the interviews also indicated that an average of 10 mucuna seeds is consumed per person during a meal. Mucuna seed is consumed both in the fresh and dry states. To prepare a stew, mucuna seeds are boiled with vegetables like garden eggs, pepper, and cocoyam leaves for about 45 minutes. The seed coat of mucuna is then removed and discarded, together with the water used in boiling. Salt is added to taste and the resultant paste boiled in oil for about 20 minutes. The result is stew which could be eaten with boiled yam, plantain, cassava, rice or cocoyam. Instead of boiling the paste in oil, it may be boiled in water with some fish or meat for about 40 minutes, to obtain a soup which is eaten with pounded yam, plantain or cassava. Most of the respondents likened the taste of mucuna to that of groundnuts, when used in soup, or of egg, when used in stew.

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The African Development Bank Group Support to Enhance Agricultural Research Development and Food Security

Aklilu AFEWORK, ***Agricultural Economist, the African Development Bank, Abidjan, Côte d'Ivoire.***

The African Development Bank Group, the major development financial institution in the continent, has as its ideal goal the overall improvement of the livelihood of the African people. To realize this goal, the Bank is fully committed to maintaining a high rate of investment in Agriculture and to strengthening the agricultural policies of its member countries. It is to this effect that the Bank maintains a significant portion of its total portfolio in agriculture.

Though the bank believes that agriculture is the engine of growth in the continent, it also recognizes that the sector faces complex and fundamental problems, such as the inadequacy of improved production technologies, unsustainable use of natural resources base for production, weak support from basic institutions, etc. These constraints must, to the extent possible, be removed in order to ensure that the role of agriculture as the motor for rural transformation is realized.

Pursuant to this general principle, one of the specific objectives of the African Development Bank is to assist with the promotion of increased agricultural production in order to help African states achieve food self sufficiency as well as other socio-economic goals. The Bank Group endeavors to provide such assistance to all institutions whose primary role is to accelerate increased production of food crops in the continent.

Among such institutions are those engaged in scientific agricultural research, and which exert sufficient effort to bring about a break-through in agricultural productivity. The Bank Group clearly acknowledges that inadequate research is a serious impediment to progress in the member countries (African members of the Bank Group). Sustained efforts to improve the quality and diversity of research work and technological dissemination would contribute substantially to faster agricultural development in Africa.

There is full conviction on the part of the Bank Group that, although research is an investment on technological development, it is a long term venture. Research, we believe, should not only focus on scientific works and studies but it must also, in the African context, serve as an important instrument for increasing the stock of trained and skilled manpower. Coordination of the work of research units in the region and strengthening national capacity for technology generation and adoption will remain important elements as well.

The Bank Group has been providing support to African Agricultural Research through: (i) concessional project loans, (ii) direct research project grants, and (iii) specific institutional support grants.

The Bank Group provides concessional loans to agricultural programmes which directly or indirectly support the development of applied agricultural research. It is perhaps important to note that such support is based on some basic, underlying principles. First of all, to the extent possible, the Bank encourages, and prefers to channel such concessional loans to research programmes or projects which form part of a larger coordinated sub-regional commodity development effort involving the participation of various specialized International Agricultural Research Centers. Secondly, the Bank believes that it is essential to strongly link funding with effectiveness and productivity. This necessitates a very close evaluation of performance and a strong donor coordination in the design of country specific research programmes. Thirdly, the Bank generally prefers to fund agricultural production projects that focus on the utilization of research results, as this provides opportunities for realizing the benefits of research efforts, in terms of increased production or improved productivity in agriculture.

Since 1986, the Bank has been providing support to research institutions using its net income resources. Since 1992, however, as the Bank's net incomes increasingly got squeezed, it began to use part of its ADF/TAF (Technical Assistance Fund) to support research. Between 1986 and 1990, the Bank provided over US 25 million dollars, from its net income resources, to support research institutions directly.
As you all will realize, the demand for grant funds is enormous while the supply has indeed been diminishing over time. So far, the Bank Group contributions were given to a large number of institutions which, by and large, focused on agricultural development research programmes. For instance, the Bank grant in 1993 was allocated to about 17 research oriented institutions, many of which are directly concerned with scientific and technological improvements in the agriculture sector. Of the 17 institutions, seven were International Agricultural Research Centers (IARCs) belonging to the Consultative Group for International Agricultural Research (CGIAR) System. I believe you are aware that the ADB Group is a member of the CGIAR System and, therefore, is committed to supporting the System. Of the seven CGIAR member centres, five are headquartered in Africa while the two based outside Africa have significant focus and emphasis on Africa's agricultural problems. We also supported ten research institutions which are not members of the CGIAR System, three of which are located outside Africa and seven within Africa; this latter category includes SAFGRAD.

Bank Group Assistance to SAFGRAD

The Bank believes that the mandate of SAFGRAD is fully compatible with the policy of the Bank. The efforts of SAFGRAD to ensure research coordination at regional level and its specific focus on main food crops deserve full support and appreciation. Given the overall resource limitations, it is important to ensure that any duplication of efforts is avoided and that available resources are mobilized to foster dynamic inter-African research cooperation. It is equally important to ensure that technical information and new research results are prompty and smoothly disseminated to member countries' National Research and Extension Systems.

The Bank Group's support to SAFGRAD began in 1990 and was followed by two more grants in 1991 and 1993. The 1993 funds were used to support the "Food Grain Production Verification Project". Cumulative financial assistance is about US 800,000 dollars. This might not appear a large sum, when viewed from the point of view of SAFGRAD's demand/needs, nevertheless, we trust it has been useful to it.

Future Bank Group Support

Support to research institutions will certainly continue to be one of the Bank's priority areas. The policy in this regard has not altered and there is no apparent reason to do so. I should, however, mention at this point that the Bank Group is currently developing much more comprehensive guidelines and procedures regarding both the submission and approval of requests pertaining to ADF grants; these will be useful to institutions which wish to benefit from the Bank's support. Thus, the indicative criteria for assessing institutions for Bank support include: (i) present research programmes and activities are oriented towards poverty reduction; (ii) there is sufficient focus on human resource development; (iii) that such research work is based in Africa, or should conduct research in Africa involving more than one country; (iv) the Bank is convinced that the institute has sound organizational structure and management; and (v) the research institute should be self-sustaining in operational and financial terms so as to avoid any perpetual dependency on donor resources. As I indicated earlier, these are being further refined and articulated but they provide a good idea of the current guiding principles.

The policy alone does not assure realization of the support. I am sure you are closely following the developments in the Bank, particularly the status of the ADF VII replenishment. The primary source of the TAF resources is the ADF allocation which is pledged by donor countries from time to time. The negotiations which should have been concluded by the end of 1993 are still on-going and we have, in this regard, already experienced over 16 months of delay. This then partly explains why the Bank Group has not provided any support to its traditional recipients in 1994 and part of 1995.

Notwithstanding the long delays and uncertainties regarding the ADF VII, we are still working on a draft proposal to our Board, which articulates the different institutions that need to be supported in the event the resources are made available, i.e., when negotiations of ADF VII are finalized. At this point in time, Mr. Chairman and members of the workshop, I can only guarantee that SAFGRAD will remain one of the potential beneficiaries of financial support from the resources of the Bank Group, but when and how much support it shall receive, I have no concrete answers. I can only guess and that guess certainly cannot be better than your guess.
I wish you success in your deliberations.

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Soutien du Groupe de la Banque Africaine de Développement à la Promotion du Développement de la Recherche Agricole et de la Sécurité Alimentaire.

Aklilu AFEWORK, *Agricultural Economist, the African Development Bank, Abidjan, Côte d'Ivoire.*

Le groupe de la Banque Africaine de Développement qui est la principale institution financière de développement du continent a pour objectif idéal l'amélioration générale des moyens d'existence des populations africaines. Pour atteindre cet objectif, la Banque s'est pleinement engagée à maintenir un taux d'investissement élevé en agriculture et à renforcer les politiques agricoles de ses pays membres. C'est l'une des raisons pour lesquelles la Banque maintient une part importante de son portefeuille total dans l'agriculture.

Si la Banque estime que l'agriculture est le moteur de la croissance sur le continent, elle reconnaît cependant que ce secteur est confronté aux problèmes les plus complexes et fondamentaux. Au nombre de ces problèmes les plus patents sont l'insuffisance de technologies de production améliorées, l'utilisation précaire de la base de ressources naturelles pour la production, le faible soutien des institutions fondamentales. Ces contraintes doivent, dans la mesure du possible, être levées pour donner à l'agriculture un rôle de moteur de la transformation rurale.

Conformément à ce principe général, l'un des objectifs spécifiques de la Banque Africaine de Développement reste l'assistance à l'accroissement de la production agricole en vue d'aider les états africains à réaliser leur autosuffisance alimentaire ainsi que d'autres objectifs socio-économiques. Le groupe de la Banque s'efforce de fournir cette assistance à toutes les institutions dont le rôle primordial consiste à accélérer l'augmentation de la production de cultures vivrières sur le continent.

Parmi ces institutions figurent celles qui s'occupent de la recherche scientifique agricole et qui déploient suffisamment d'efforts pour apporter des innovations dans la productivité agricole.

Le groupe reconnaît clairement que l'insuffisance de recherche est une entrave au progrès des pays membres (membres africains du groupe de la Banque). Des efforts soutenus tendant à améliorer la qualité et la diversité des travaux de recherche et la diffusion des technologies contribueraient grandement à accélérer le développement agricole en Afrique.

Le groupe de la Banque a la ferme conviction que la recherche est un investissement dans le développement technologique et est également conscient qu'il s'agit d'une entreprise de longue haleine. La recherche, nous le croyons, ne doit pas seulement être axée sur les travaux et études scientifiques, mais doit également servir d'instrument important pour augmenter le capital de ressources humaines formées et qualifiées. La coordination des activités des entités de recherche de la région ainsi que le renforcement des capacités nationales de production et d'adoption de technologies resterons également un élément important.

Le groupe de la Banque soutient la recherche agricole africaine par a) des prêts de projet à des conditions favorables, b) des subventions directes à des projets de recherche et c) des subventions spécifiques d'appui institutionnel.

Le groupe de la Banque accorde des prêts à des conditions favorables aux programmes agricoles qui, directement ou indirectement soutiennent le développement de la recherche agricole appliquée. Il importe sans doute de noter que ce soutien est basé sur quelques principes fondamentaux. Tout d'abord, la Banque, dans la mesure du possible, encourage et préfère canaliser ces prêts concessionnels vers des programmes ou projets de recherche qui entrent dans le cadre d'efforts plus élargis et coordonnés de développement agricole sous-régional impliquant la participation de différents centres internationaux spécialisés de recherche agricole. Deuxièmement, la banque croit qu'il est essentiel de lier étroitement le financement et l'efficacité et la productivité. Ceci exige une évolution très approfondie de la performance et une coordination rigoureuse des donateurs dans l'élaboration des programmes spécifiques nationaux de recherche. Troisièmement, la Banque préfère généralement financer les projets subséquents de production qui mettent l'accent sur l'utilisation des résultats de recherche dans la mesure où cela donne l'occasion de tirer profit des efforts de recherche en augmentant la production ou en améliorant la productivité de l'agriculture.

Depuis 1986, la Banque soutient les institutions de recherche en utilisant ses revenus nets. Cependant, depuis 1992, du fait que ses revenus nets sont devenus de plus en plus restreints, la Banque a commencé à utiliser une partie de son FAD/FAT (Fonds d'Assistance Technique) pour soutenir la recherche. Entre 1986 et 1990, la Banque a dégagé plus de 25 millions de dollars US de ses revenus nets pour soutenir directement les institutions de recherche.

Comme vous vous en rendez-compte, la demande de subventions est énorme alors que l'offre a diminué effectivement au fil du temps. Jusqu'ici, les contributions du groupe de la Banque ont été accordées à un grand nombre d'institutions qui d'une manière générale se sont concentrées sur des programmes de recherche pour le développement agricole. Par exemple en 1993, la subvention de la Banque a été allouée à environ 17 institutions de recherche dont beaucoup s'occupent directement des améliorations scientifiques et technologiques dans le secteur agricole. Sur les 17 institutions, sept étaient des Centres Internationaux de Recherche Agricole (CIRA) appartenant au Système du Groupe Consultatif pour la Recherche Agricole International (GCRAI). Je suppose que vous savez que le groupe de la BAD est membre du système du GCRAI et a donc l'obligation de soutenir le système. Sur les sept Centres membres du GCRAI, cinq se trouvent (sont basés) en Afrique tandis que deux sont basés hors d'Afrique mais mènent cependant d'importantes activités axées sur les problèmes agricoles de l'Afrique. Nous avons également soutenu dix institutions de recherche qui ne sont pas membres du Système du GCRAI et dont trois sont basées hors d'Afrique et sept en Afrique. Le SAFGRAD entre dans cette catégorie.

Assistance du Groupe de la Banque au SAFGRAD

La Banque estime que le mandat du SAFGRAD est tout-à-fait compatible avec la politique de la Banque. Les efforts du SAFGRAD pour assurer la coordination de la recherche au niveau régional et l'accent qu'il a particulièrement mis sur les principales cultures vivrières méritent d'être entièrement soutenus et reconnus. Compte tenu des ressources généralement limitées, il importe d'éviter toute duplication des efforts et de mobiliser les ressources disponibles pour promouvoir une coopération inter-africaine dynamique en matière de recherche. Il importe également de veiller à ce que les informations techniques et les nouveaux résultats de recherche soient diffusés en temps opportun et de manière appropriée auprès des Centres Nationaux de Recherche.

Le groupe de la Banque a commencé à soutenir le SAFGRAD en 1990 et lui a accordé ensuite deux autres subventions en 1991 et 1993. Les fonds octroyés en 1993 ont servi à appuyer le "Projet de Vérification de Technologies de Production de Cultures Vivrières". L'assistance fournie dans l'ensemble se chiffre à 1 - 2 millions de dollars. Ceci pourrait ne pas être considéré comme une importante somme si l'on tient compte des demandes et besoins des institutions. Nous espérons néanmoins que le SAFGRAD a pu en tirer profit.

Soutien Futur du Groupe de la Banque

Le soutien aux insitutions de recherche continuera certainement à être un des domaines prioritaires de la Banque. A cet égard sa politique ne semble pas avoir changé et il n'y a apparemment aucune raison pour qu'il en soit ainsi.

Je dois cependant faire remarquer sur ce point que le groupe de la Banque élabore actuellement des directives et des procédures plus globales en ce qui concerne la soumission et l'approbation des requêtes de subventions du FAD. Il est à espérer que lorsque ces procédures seront finalisées, elles serviront de document utile pour les institutions qui souhaitent bénéficier du soutien de la Banque.

Le cadre général actuel de sélection ou de priorité de bénéfiaires potentiels au sein des instituts de recherche met l'accent sur les aspects suivants ou en d'autres termes, les critères indicatifs de détermination des institutions pouvant bénéficier du soutien de la Banque sont les suivants : a) les programmes et activités de recherche visent à réduire la pauvreté b) l'accent est suffisamment mis sur le développement des ressources humaines c) ces programmes de recherche sont basés en Afrique ou devraient avoir des volets de recherche en Afrique touchant plus d'un pays, d) la Banque est convaincue que l'institut a une structure organisationnelle et une gestion saines, et e) l'institut de recherche devrait être autonome sur le plan opérationnel et financier de manière à éviter une dépendance des ressources des donateurs. Comme je l'ai déjà indiqué ces points sont actuellement peaufinés et explicités et donneront aux membres une idée de ce qu'est le principe directeur de la Banque aujourd'hui.

La politique seule n'assure pas la concrétisation du soutien. Je suis persuadé que vous suivez attentivement l'évolution de la Banque, particulièrement l'état du réapprovisionnement du FAD VII. La principale provenance des ressources du FAT est l'allocation du FAD que les pays donateurs s'engagent de temps en temps à honorer. Les négociations qui auraient dû être conclues vers la fin de l'année 1993 sont toujours en suspens et à cet égard, nous accusons déjà un retard de plus de 16 mois. Ceci explique en partie pourquoi le groupe de la Banque n'a pas apporté de soutien à ses bénéficiaires traditionnels en 1994 et même pendant l'année en cours (1995).

En dépit des importants retards et des incertitudes concernant FAD VII, nous travaillons toujours sur un projet de proposition à soumettre à notre conseil, qui spécifie les différentes institutions nécessitant un soutien au cas où les ressources seront disponibles, c'est-à-dire lorsque les négociations de FAD VII seront finalisées. A l'heure actuelle, M. le Président et Messieurs les participants à cet atelier, je peux garantir seulement que le SAFGRAD restera l'un des bénéficiaires potentiels de ce soutien des ressources du groupe de la Banque.

Cependant je ne puis donner de réponses concrètes quant au moment et à l'importance de ce soutien. Je ne peux que présumer et cette présomption ne peut être certainement meilleure à la vôtre.

Je souhaite plein succès à vos travaux.

Merci.

ANNEX I

Summary and Recommendations of Technical Working Groups

Résumé et Recommandations des Groupes de Travail Techniques

SUMMARY AND RECOMMENDATIONS OF TECHNICAL WORKING GROUPS

A Regional Workshop on Technology Options and Transfer was held from 26 to 29 April, 1995 in Abidjan, Côte d'Ivoire, under the auspices of the Semi-arid Food Grain Research and Development (SAFGRAD) Project of the Scientific, Technical and Research Commission of OAU.

Two technical Working Groups (i.e. Technology Options and Transfer) have further deliberated on the technical and policy issues that led to the following summary and recommendations:

1. Lessons

The following lessons were identified:

1.1 It was noted that a number of proven working agricultural technologies do exist, but will need to be "packaged" to accelerate food production in the 21st century.

1.2 There exists in each country (SSA) an organized extension system that has led to some measure of technology adoption. Success stories in technology transfer required strong research/extension-farmer linkages, availability and delivery of inputs, technology multiplication and diffusion schemes and marketing channels.

1.3 The combined use of Chemical fertilizer and improved seed technology are essential for attaining food security to cope with populations growth and sustain soil fertility.

1.4 The participation of farmers is crucial in technology development and transfer. Unless farmers are empowered to manage their own on-farm resources and available technologies, it is unlikely that both food security and environmental protection can be achieved.

2. Intensification of Agriculture

Intensification of agriculture is vital for economic growth and poverty alleviation. It is, therefore, a strategic option for attaining food security in sustainable manner.

Considerable discussion took place to define the parameters, components and the required policy environment for the intensification of agriculture. The scope for the intensification of agriculture in semi-arid Africa has improved, because of availability of new generation of technologies developed over the last two decades. Some of these technologies include.

2.1 Drought, pest resistance cultivars, efficient soil and water conserving practices, combined use of chemical fertilizer and organic matter.

2.2 Animal traction has enabled farmers not only to expand the area of land cultivated, but also to diversify farm-entreprises and to relieve labour constraints.

2.3 Adequately functioning input supply systems and access to credits, including delivery, distribution, etc. are essential to double or triple agricultural production.

2.4 The integration of livestock and crop production has been promoted in recent years to both enhance the recycling of on-farm resources and for improving soil fertility.

2.5 The intensification of agriculture should be based on market demand and beyond to meet subsistence needs.

3. Technology Transfer Issues

Comparative analysis of the agricultural extension systems of three countries (i.e. Nigeria, Burkina Faso and Senegal) was made. The extension system in these and other countries have evolved differently. But, all inherited technology transfer infrastructures and approach of the colonial era, which emphasized on the production and export of commercial crops. The last three decades of extension experience showed that several approaches and models of technology transfer do exist. Several countries in Africa have adopted the modified Training and Visit (T and V) system which has been promoted by the World Bank. The T and V approach has been successful in linking adaptive research with extension and farmers and distribution of inputs. It has been, however, less cost effective and women were not full partners in the transfer of agricultural production technologies. The following issues of technology transfer were stressed:

3.1 The linkage between research and extension is a key issue, since it could much influence the generation, transfer and adoption of technologies.

3.2 The participatory approach of extension for transferring research results will enable farmers to influence the delivery of technology and inputs.

3.3 There has been neglect to involve women in both research and extension; and most technologies available have been male-biased.

3.4 Lack of adequate funding for training of extension technicians, officers, including women and youth.

4 Recommendations

Considering the challenges of attaining food security; aware of environmental degradation and the need that African agriculture should be competitive to recapture external markets; to ensure that growth in agriculture will spur economic growth in related sectors, the following recommendations were made:

4.1 To develop a research strategy that could strike a balance between sustainable agricultural development and the restoration of resource base through an efficient management of natural resources.

4.2 The choice of technologies in an integrated farming enterprise should ensure complementarily in terms of resource use and in income generation particularly at on-farm level.

4.3 There is a need to intensify research to resolve problems of soil fertility and water use efficiency and conservation.

4.4 Governments should put in place institutions that could provide the enabling policy environment to enhance production and commercialization of agriculture.

4.5 The following research on Technology Transfer Systems (TTS) were proposed:

- Evaluative study of existing TTS to determine why agricultural technology transfer has been generally low.
- The determination of point entry of TTS in technology development and transfer continuum.
- Study on community-based TTS for cost effectiveness and sustainability.

RESUME ET RECOMMANDATIONS DES GROUPES DE TRAVAIL TECHNIQUES

Un Atelier Régional sur les Options et le Transfert de Technologies s'est tenu du 26 au 29 Avril 1995 à Abidjan, Côte d'Ivoire, sous les auspices du Projet de Recherche et de Développement des Cultures Vivrières dans les Zones Semi-Arides d'Afrique (SAFGRAD) de la Commission Scientifique, Technique et de la Recherche de l'OUA.

Deux groupes de travail techniques (i.e Options et Transfert de Technologies) se sont en outre penchés sur les questions techniques et politiques, avec pour conclusions le résumé et les recommandations ci-après :

1. Enseignements

Les enseignements suivants ont été tirés.

1.1. Il a été noté qu'il existe effectivement un certain nombre de technologies agricoles qui ont fait leur preuve mais doivent être utilisées sous forme de "paquet" pour accélérer la production vivrière au cours du 21e siècle.

1.2. Chaque pays (de l'Afrique Sub-Saharienne) dispose d'une structure de vulgarisation qui a permis un certain degré d'adoption de technologies. Les exemples de réussite en matière de transfert de technologies commandent l'établissement de liens solides recherche/vulgarisation/paysan, la mise à disposition et la fourniture d'intrants, des structures de multiplication et de diffusion de technologies ainsi que des circuits de commercialisation.

1.3. L'utilisation combinée d'engrais chimiques et de semences améliorées s'avère essentielle pour la réalisation de la sécurité alimentaire en vue de faire face à l'accroissement démographique et à assurer la fertilité durable des sols.

1.4. La participation des paysans est cruciale dans la mise au point et le transfert des technologies. Sans la responsabilisation des paysans pour la gestion de leurs propres ressources agricoles et des technologies disponibles, il est peu probable que la sécurité alimentaire et la protection de l'environnement pourront être réalisées.

2. Intensification de l'Agriculture

L'intensification de l'Agriculture est vitale pour la croissance économique et l'atténuation de la pauvreté. Il s'agit donc d'une option stratégique pour la réalisation d'une sécurité alimentaire durable.

La définition des paramètres, des composantes et du cadre politique requis pour l'intensification de l'agriculture a été longuement débattue. Les possibilités d'intensification de l'agriculture en Afrique semi-aride se sont améliorées à cause d'une nouvelle génération de technologies mises au point au cours des deux dernières décennies. Ces technologies comprennent entre autres :

2.1. Les cultures résistantes à la sécheresse et aux ravageurs, les pratiques efficaces de conservation du sol et de l'eau, l'utilisation combinée des engrais chimiques et de la matière organique.

2.2. La traction animale qui a permis aux paysans non seulement d'accroître les superficies cultivées mais également de diversifier les activités agricoles et de subir moins de contraintes de travail.

2.3. Les systèmes de fourniture d'intrants fonctionnant bien et l'accès aux crédits, y compris la livraison, la distribution etc. sont essentiels pour doubler ou tripler la production agricole.

2.4. L'intégration de l'élevage à la production de cultures a été encouragée au cours des dernières années afin de promouvoir le recyclage des ressources agricoles aussi bien que d'améliorer la fertilité du sol.

2.5. L'intensification de l'agriculture devrait se faire sur la base de la demande du marché et au delà pour la satisfaction des besoins de subsistance.

3 Questions de Transfert de Technologies

Une analyse comparative a été faite des Systèmes de Vulgarisation Agricole de trois pays (i.e. Nigeria, Burkina Faso et Sénégal). Dans ces pays et dans les autres pays, les systèmes de vulgarisation ont évolué difficilement. Cependant, tous ont hérité d'infrastructures et d'approches de transfert de technologies de l'époque coloniale, qui mettaient l'accent sur la production et l'exploitation de cultures commerciales. Il a été démontré au cours des trois dernières décennies qu'il existe plusieurs approches et modèles de transfert de technologies. Plusieurs pays d'Afrique ont adopté le système modifié de Formation et Visite (F et V) qui a été promu par la Banque Mondiale. L'approche F et V a connu du succès dans la liaison entre la recherche adaptative, la vulgarisation et les paysans et la distribution d'intrants. Cependant, elle a été moins rentable et les femmes n'étaient pas des partenaires à part entière dans le transfert des technologies de production agricole. Les questions suivantes de transfert de technologies ont été soulignées :

3.1 Le lien entre la recherche et la vulgarisation est crucial, dans la mesure où il peut grandement influencer la production, le transfert et l'adoption de technologies.

3.2 L'approche participative de la vulgarisation pour le transfert des résultats de recherche permettra aux paysans d'influencer la livraison des technologies et des intrants.

3.3 Les femmes ont été négligées aussi bien dans la recherche que dans la vulgarisation, et la plupart des technologies disponibles ont surtout été destinées aux hommes.

3.4 L'insuffisance de fonds pour la formation des techniciens et cadres de vulgarisation, y compris les femmes et les jeunes.

4 Recommandations

Considérant les défis que pose la réalisation de la sécurité alimentaire; conscients de la dégradation de l'environnement et de la nécessité de rendre l'agriculture africaine compétitive en vue de récupérer les marchés externes et faire en sorte que la croissance agricole stimule la croissance économique dans les secteurs apparentés, les groupes de travail techniques ont recommandé :

4.1 Qu'une stratégie de recherche soit élaborée, qui puisse rétablir l'équilibre entre le développement agricole durable et la restauration de la base de ressource par une meilleur gestion des ressources naturelles.

4.2 Que le choix de technologies dans un système de production intégré assure la complémentarité en matière d'utilisation de ressources et de génération de revenus particulièrement au niveau de l'exploitation agricole.

4.3 Que la recherche soit intensifiée en vue de résoudre les problèmes de fertilité du sol, d'utilisation efficace et de conservation de l'eau.

4.4 Que les gouvernements mettent en place des institutions susceptibles de fournir un cadre politique propice à la promotion de la production et de la commercialisation des produits agricoles.

4.5 Les thèmes suivants de recherche sur les Systèmes de Transfert de Technologies (STT) ont été proposés :

- Etude d'évaluation des STT pour déterminer les raisons pour lesquelles le transfert de technologies agricoles a généralement été faible.

- Détermination du point d'entrée des STT dans le développement et le processus continu de transfert de technologies.

- Etude des STT à base communautaire pour la rentabilité et la durabilité.

ANNEX II

- Keynote address
- Opening and closing remarks

- Discours d'orientation
- Discours d'ouverture et de clôture

Allocution d'Ouverture du Représentant du Ministre de L'Agriculture et des Ressources Animales L'Atelier Régional de Réflexion sur les Options et Systèmes de Transfert de Technologies

Abidjan le 26 Avril 1995.

Monsieur le Secrétaire Exécutif de l'OUA/CSTR,
Monsieur le Représentant de la BAD,
Monsieur le Coordinateur International de l'OUA/SAFGRAD,
Monsieur le Directeur Général de l'IDESSA,
Mesdames, Messieurs,
Honorables Délégués,

Monsieur Lambert Kouassi Konan, Ministre de l'Agriculture et des Ressources Animales, empêché, m'a chargé de vous apporter, à vous tous, Honorables Séminaristes, ses salutations fraternelles tout en vous exprimant ses vifs regrets de ne pas être en mesure d'être présent à cet important atelier régional de réflexion sur les "Options et systèmes de transfert de technologies".

L'Afrique, notre Afrique doit cesser d'offrir au monde les horreurs des guerres fratricides, le spectacle désolant des famines perpétuelles pour se pencher résolument sur la recherche des voies et moyens pour sortir des carcans du sous-développement qui semble lui coller telle une fatalité congénitale. L'Afrique doit cesser d'être la terre des complaintes.

C'est pourquoi, des rencontres comme celles-ci, où doivent se confronter des connaissances et les expériences, en vue d'assurer de façon durable, une meilleure adéquation entre les besoins et la sécurité alimentaire, ne peuvent qu'emporter l'adhésion de tout Africain.

Aussi la Côte d'Ivoire, qui accorde une très grande importance à la coopération entre peuples en général, et à la coopération sud-sud en particulier, se félicite-elle d'abriter de telles assises.

C'est le lieu de remercier et de féliciter les initiateurs de cette rencontre, je pense à l'Organisation de l'Unité Africaine et à la Banque Africaine de Développement.

Honorables Délégués,

Pendant quatre jours, vous aurez à réfléchir pour proposer à l'Afrique les voies et méthodes, qui lui permettent de bien nourrir une population en croissance régulière, grâce à l'exploitation judicieuse de ses nombreuses potentialités.

La Côte d'Ivoire notre pays, est très attentive aux résultats prometteurs de votre rencontre.

C'est sur cette note d'espoir, qu'au nom du Ministre de l'Agriculture et des Ressources Animales, de Côte d'Ivoire, son Excellence Lambert Kouassi Konan, je déclare ouvert l'Atelier Régional sur les Options et Systèmes de Transfert de Technologies tout en souhaitant plein succès à vos travaux et un agréable séjour à nos visiteurs.

Je vous remercie.

Opening Address by the Representative of the Minister of Agriculture and Animal Resources at the Regional Workshop on Technology Options and Transfer Systems

Abidjan 26 April 1995

Distinguished Executive Secretary of OAU/STRC
Honourable Representative of the ADB
The International Coordinator of OAU/SAFGRAD
The Representative of the European Union
The Director Général of IDESSA
Ladies and gentlemen
Honourable Delegates

Mr Lambert Kouassi Konan, Minister of Agriculture and Animal Resources being excused has instructed me to convey to all of you, honourable participants, his fraternal greetings while expressing his deep regrets for not being able to attend this important workshop on "Technology options and transfer systems".

Africa, our Africa must cease providing the world with fratricide horrors and distressing sight of perpetual famines and definitely seek the ways and means to get rid of the yoke of under-development which seems to cling to it like a congenital fatality. Africa must no longer be the land of laments.

That is why meetings like this one where knowledge and experiences must be confronted in order to achieve a better adjustment between food requirements and security cannot but be approved by any African. Thus, Côte d'Ivoire which attaches very great importance to cooperation between peoples in general and to south-south cooperation in particular is very pleased to host this meeting.

Let me thank and congratulate the instigators of this meeting, namely the Organization of African Unity and the African Development Bank.

Honourable Delegates,
During four days you will have to reflect in order to propose to Africa the ways and means to provide adequate food to a steadily increasing population through a judicious exploitation of its numerous potentialities.

Côte d'Ivoire our country pays great attention to the promising results of your meeting.

It is on this note of hope that on behalf of the Minister of Agriculture and Animal Resources, his Excellency Lambert Kouassi Konan, I declare the Regional Workshop

on Technology options and transfer systems open while wishing you full success in your deliberations and pleasant stay to our guests.
Thank you.

Overview of technology Transfer Options in African Agricultural Research Systems

Prof. J. A. EKPERE, Executive Secretary, Scientific, Technical and Research Commission, Organisation of African Unity (OAU/STRC), LAGOS, Nigeria.

Mr. Chairman,
Honourable Minister,
Representatives of the African Development Bank,
Members of the Diplomatic Corps,
Distinguished Agricultural Research Scientists,
Ladies and Gentlemen:

Prologue

Let me predicate my short address to this very important Workshop, this morning, by first conveying to you all, the goodwill, warm and sincere greetings of his Excellency Dr. Salim Ahmed SALIM, Secretary General, Organization of African Unity, Addis Ababa, Ethiopia. As supervisory organizer of this Workshop, let me extend my personal warm welcome to you all. Permit me to extend, on your behalf, to the President and Peoples of the Republic of Cote d'Ivoire, our sincere appreciation for their warm welcome, unparalleled hospitality since our arrival in this beautiful African city of Abidjan and the excellent facilities placed at our disposal for the effective implementation of this Workshop.

At a time when our sub-region is bedeviled with a lot of problems, not the least of which is food self-sufficiency and food security, a Workshop to discuss technology transfer options to meet the challenges of food production in the 21st Century, could not have come at a more opportune time. The National Agricultural Research Services and International Agricultural centres have worked relentlessly over the last three decades developing improved agricultural technologies with a view to increasing food production. Formative assessment of these efforts suggest that the desired food increases remains a mirage. One explanation has been in ineffective technology transfer approaches.

Introduction

A foremost African Scientist, recently stated the obvious when he indicated that "success in the sustainable economic development of any nation is practically impossible outside of the development of science and technology capacity and the practical application of it to the required extent"[1]. While agreeing with his assertion, I want to pitch my remarks this morning to complement that section of his opinion which speaks to "the practical application of technology to the extent possible". This is because, the practical application of an appropriate technology "to the desirable extent and with accompanying proportionate benefit" is only possible with the promotion, acquisition and skillful use of the given technology all of which subsume a transfer process.

The rate of technological growth, investment in research and development and overall capacity to absorb borrowed, locally developed and/or imported technology has been identified as one of the contemporary constraints impeding the successful implementation of development programmes in Africa. This position is substantiated by an expert opinion that, "over the years, Africa has achieved a high record in infrastructural development; of roads, airports, seaports, communication, educational institutions, health institutions, power supply, water supply..... dams for irrigated agriculture etc. But these installations and establishments, as necessary and indispensable as they are, have by and large served mainly as general purpose assets and facilitators of trade and of consumer goods production. They only form a part of the wider infrastructure which is required for the entrenchment of a scientific capacity and the local production of the capital goods needed for a self-reliant industrialization. That they are not a sufficient infrastructure for national economic take-off and sustainable growth is demonstrated by the fact that despite our possessing them, we are not able to replicate them without reference to excessive and costly importations, nor are we able to service them without resorting to imported materials and spare parts". Let me hasten to add however, that the undesirable situation occasioned by the above analyses of the African industrial sector is being addressed by its National and Sub-Regional Centres for Engineering Design and Development of Technology. Perhaps the major weakness of these agencies is their technology transfer components which have made the transition from research to practice, difficult to achieve.

In Agriculture, it has been argued that the problem of low productivity within the sector is due more to low levels of adoption of available technologies complicated by inefficient application due manly to poor skills in manipulating the technologies. Both problems relate directly to ineffective and inefficient technology transfer mechanisms rather than total absence of appropriate technologies. It has been suggested that National Agricultural Research Centres could benefit immensely from the world stock of available agricultural technology if they can organize an effective technology transfer capability, backstopped by a well managed adaptive research system. Without meaning to de-emphasize basic research, this statement underscores the importance of technology transfer and necessary absorption/adaptive capacity for nations with low resource endowment.

There is historical evidence that the dawn of science with contribution from research, documented information, communication and trade is a major stimulus for technological innovation. In Africa, indigenous research and development has always been regar-

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[1] Professor G.O. EZEKWE, October, 1993, "A National Science and engineering Infrastructure : The Agenda for a Sel-reliant Growth for Nigeria". The Nigerian Academy of Science, October, 1993 Lecture, LAGOS, PP.1.

ded as a necessary pre-condition for effective technology transfer. This is because a well planned and implemented research and development capability provides not only a firm base for adapting foreign and indigenous national technologies, it facilitates their absorption and more importantly, their exploitation by further technical development. The transfer of technologies across national boundaries or between enterprise sectors within a single country is an essential factor in growth and development industrial and agricultural. It provides the desired mechanism for moving from one stage of development to another, as well as the means for forcing change. It provides the finance necessary to support further technological change, while enhancing the competitive effects of lower cost techniques.

A Concept of Research, Transfer and Technology Transfer

Kaimowitz[2] and his associates in a recent analysis identified key conceptual definitions in the study of technology transfer. They defined that the "the terms research and technology transfer have both functional and institutional meanings. In their functional usage, they describe certain activities in the process of technology development and delivery".

In the case of research, these activities include discovery, exploratory development and technology consolidation. Discovery is conceived as the process of collecting information and/or searching for relationships between variables, the specific usefulness of which, is as yet, undetermined. Often, this is also referred to as basic research.

Exploratory development is the identification, exploration applied understanding and control of the interaction between a proposed technology and the physical, economic, or social environment in which it will ultimately be used. This can be thougth of, as applied research.

Webster[3] defines technology as "a technical method for achieving a practical purpose". Roling[4] describes technology as "the software and hardware available for controlling the environment for human purposes. The software, he says, consists of methods and skills while the hardware is made up of physical objects, such as tools, equipments, genetic material etc." The development of technology can be based on the advance of science and hence, on the application of research findings. Fresco[5], indicates that technology is the means by which inputs are transformed into outputs. For the purpose of

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2 Kaimowitz, D. K., Snyder, M. and Engel, P., 1989. "A conceptual Framework for studying links between agricultural Research and Technology Transfer in Developing Countries" Linkage Theme Paper N°.1, The Hague: ISNAR.

3 Webster Dictionary - 5th Edition

4 Roling, N. (1989). "The Agricultural Research-Technology Interface : A Knowledge Systems Perspective" ISNAR Linkage Theme Paper N°.6, P.7.

5 Fresco, L.O., (1986), "Cassava and Shifting Cultivation: A Systems Approach to Agricultural Technology Development". Royal Tropical Institute, Amsterdam, The Netherlands.

this discussion, Technology can be operationalized as an idea, a product, an input, information or a way of doing things. It may be physical, tangible or abstract. Technology consolidation is the process of translating the knowledge obtained previously in basic or applied research into specifications for the new product or information and of the end-user for whom the technology will be appropriate. The information or new materials is formulated in the format which will be used in its delivery. While consolidation has some aspects of adaptive research, it goes beyond that. It also includes all the work involved in determining how to present and package a technology and identifying exactly who might be interested in using it.

Technology production is the process of physically producing the materials (physical inputs or information materials) in sufficient quantity for distribution to intended clients and of making these materials available to those responsible for technology delivery.

Technology delivery is where the technology is actually packaged, promoted and distributed. This normally occurs through a multiplicity of channels and events. The target groups get little bits and pieces of information, some of it complimentary and some contradictory, from many different sources and they assess and integrate this information over time in their decision process in relation to technology acquisition and use.

Monitoring and evaluating utilization involves the assessment of whether prospective end-users have acquired and decided to fully or partially adopt, adapt, or reject the proposed technologies, and the reasons for those decisions. The technology transfer process covers technology production, the delivery of technologies as well as the monitoring and evaluation of their utilization.

All, or at least, many of these activities occur simultaneously during the development and delivery of a new technology. While both common sense and the literature implies that there is some logical progression between them 'McDermott[6] believes, there is no reason to assume that all technologies must pass though a fixed set of stages in a chronological sequence.

For instance, work may begin with exploratory development, rather than discovery. It may also be technically appropriate for new research to be undertaken in relation to a technology that is already in the process of consolidation.
The term research and technology transfer is also used to denote the units or individuals that specialize in this activity. Thus, we have Research Centres, Researchers, Technology Transfer Workers, etc.

The correspondence between the two usages is far from perfect. A great variety of different groups and institutions besides just "Researchers" are involved in discovery,

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[6] McDermott, J.K., (198'), Making Extension Effective : The Role of Extension/Research Linkages", in Agricultural Extension Worldwide, Edited by Rivera, W. and Shiram, S. New York : Croom helm.

explanatory development and technology consolidation. Researchers are also involved in technology production and delivery as well as other activities in the process. The essence' of this short analysis is to call attention to the process of technology development and transfer in the abstract and disabuse our minds from believing that the process is simple and involves discrete individuals and disciplines operating independently of each other.

Mr. Chairman,
Distinguished Scientists,
Ladies and Gentlemen:

The concepts and ideas we are gathered here to attempt to understand and discuss in the next two days is, an admixture of complex issues, requiring reflective thinking and participation of both natural, physical, biological and social Scientists. There is evidence that the unacceptably low rate of technology development and ineffective technology transfer process in Africa is not accidental, but the result of a cumulative effect of policies and actions of all actors in the process -governments, donors, National Agricultural Research Systems, International Agricultural Research Centres, Regional and Sub-Regional Research Institutions, Universities and the private sector. They all share in the responsibility for the food crisis confronting Africa. There is therefore a need to jointly seek a new orientation to the problems of increased food production and face up to the challenge of the 21st Century. The process will be evolutionary, long term in perspective and will require persevering commitment and a willingness to re-examine the traditional approach to agricultural research, technology development, packaging and transfer.

This Workshop has been designed to address the twin, but inter-related issues of Technology Options for Food Grain Production and Technology Transfer Systems. It is my hope that in discussing technology options, due consideration will be given to dwindling fortunes of Africa, in the acquisition of exogenous technologies requiring the application of high inputs for success. This Workshop should consider a long-term vision of appropriate technology development predicated on low input use by poor resource farmers. The emphasis should be on indigenous food grains of importance in the dietary requirements of the population rather than exotic grains.

The objective should be towards the maintenance of sustainable agricultural production systems that are environment friendly, rather than systems that are exploitative of the environment, resulting in ecological degradation. Your deliberations must focus on the optimal process and content for improvement and achievement of the best fit technology options for food grain production, as well as the key mechanism to support their implementation in the 21st Century.

The challenge of Technology Transfer to meet the food grain requirements of the 21st Century is exacerbated by the low level of research on the technology transfer process itself. There seem to be an implicit assumption in the technology development delivery and transfer sub-system that technology development is a research activity and that technology transfer is the practical follow-up or a pseudo-research activity involved in technology delivery. Consequently, assessment of various approaches to technology transfer has been normative and descriptive, devoid of critical research analysis and therefore, lacking in predictive scientific basic for failure and success. The knowledge base for research - technology transfer linkages, suffers as a consequence. In this Workshop, you will be discussing on-farm research verification trials and assessing the efficiency and experiences of current approaches of extension services and technology transfer systems. I implore you to be more scientific, methodical and critical in your assessment, ensuring as much objectivity as possible.

Mr. Chairman,
Distinguished Ladies and Gentlemen :

The task before us in the next few days is a difficult one. Let us face it with the seriousness that it deserves. Our deliberations should be seen as a major contribution to knowledge and practice on how Africa will cope with the food grain problem in the 21st Century. I have no doubt that with the collective wisdom of us all, the objective of this Workshop will be accomplished. While wishing you a successful Workshop, I thank you for your attention.

Vue générale des options de Transfert de Technologies dans les Systèmes de Recherche Agricole en Afrique

Professeur J. A. EKPÉRÉ, *Secrétaire Exécutif, Commission Scientifique, Technique et de la Recherche de l'Organisation de l'Unité Africaine (OUA/CSTR) Lagos, Nigeria.*

Monsieur le Président,
Excellence Monsieur le Ministre
Messieurs les Réprésentants de la Banque Africaine de Developpement
Messieurs les Membres du Corps Diplomatique,
Messieurs les Spécialistes de la Recherche Agricole.
Mesdames et Messieurs.

Prologue

Permettez-moi d'entamer mon bref discours à ce très important atelier qui s'ouvre ce matin, en vous adressant l'expression de la haute considération et les salutations chaleureuses et sincères de son Excellence Dr Salim Ahmed Salim le Secrétaire Général de l'Organisation de l'Unité Africaine à Addis-Abeba en Ethiopie. En tant qu'organisateur général de cet atelier, je voudrais vous souhaiter personnellement et chaleureusement à tous la bienvenue. En votre nom, je voudrais exprimer nos sincères remerciements au Président et au Peuple de la République de Côte d'Ivoire, pour leur accueil chaleureux, l'hospitalité sans pareil qui nous a été accordée depuis notre arrivée dans cette belle ville africaine d'Abidjan et les excellentes facilités mises à notre disposition pour la tenue effective de cet atelier.

A une période où notre sous-région souffre d'un lot de problèmes dont les moindres ne sont pas ceux d'autosuffisance ou de sécurité alimentaire, un atelier pour examiner les options de transfert de technologies en vue de relever les défis de la production alimentaire au 21è siècle n'aurait pu se tenir à un moment plus opportun. Les Services Nationaux de Recherche Agricole et les Centres Internationaux de Recherche Agricole ont travaillé sans relâche au cours des trois dernières décennies pour mettre au point des technologies agricoles améliorées permettant d'accroître la production vivrière. Une évaluation formelle de ces efforts laisse penser que les augmentations de production vivrière souhaitée restent un mirage. L'une des explications de cette situation a été l'inefficacité des approches du transfert de technologies.

Introduction

Un éminent scientifique africain a récemment affirmé avec juste raison que "le développement économique durable de tout pays est pratiquement impossible en dehors du développement de la science et de la technologie et de leur application au niveau requis"[7]. Tout en approuvant cette assertion je voudrais ce matin compléter cette opinion en disant "l'application pratique de la technologie autant que possible", car l'application pratique d'une technologie appropriée à un degré souhaitable et avec un profit proportionnel n'est possible qu'avec la promotion, l'acquisition et l'utilisation avisée de la technologie donnée. Tout ceci suppose un processus de transfert.

Le taux de croissance économique, l'investissement dans le domaine de la recherche et du développement et la capacité générale d'absorption de technologies empruntées, mises au point localement et/ou importées ont été identifiés comme l'une des contraintes actuelles au succès des programmes de développement en Afrique. Ce point de vue est étayé par une opinion d'experts selon laquelle "au fil des années, l'Afrique a atteint un niveau élevé de développement infrastructurel : routes, aéroports, ports maritimes, connunication, institutions d'enseignement, établissements sanitaires, alimentation en énergie, en eau... barrages pour l'irrigation, etc. Mais ces installations et établissements, aussi nécessaires et indispensables soient-ils ont dans l'ensemble généralement servi d'atouts et de faciliteurs du commerce et de la production de biens de consommation. Ils ne constituent qu'une partie de l'infrastructure plus élargie qui est nécessaire à l'implantation d'une capacité scientifique et à la production locale de biens requis pour une industrialisation autosuffisante. L'insuffisance d'infrastructures pour le décollage économique national et la croissance durable est démontrée par le fait que bien que nous en ayons, nous ne sommes ni capables de les reproduire sans avoir recours à des importations excessives et coûteuses, ni capables de les exploiter sans importer du matériel et des pièces détachées. Je m'empresse cependant d'ajouter que la situation désagréable occasionnée par l'analyse ci-dessus du secteur industriel africain est actuellement l'objet de préoccupation des Centres Nationaux et Sous-Régionaux d'Engeniering et de Développement Technologique. Sans doute que la principale faiblesse de ces organismes réside dans leurs composantes de transfert de technologies, ce qui a rendu difficile le passage de la recherche à la pratique.

Dans le domaine agricole il a été dit que la faible productivité du secteur est dûe surtout à des faibles niveaux d'adoption de technologies disponibles en plus de l'application inefficace de celles-ci principalement en raison de l'insuffisance des capacités de maîtriser des technologies. Ces problèmes sont directement liés aux mécanismes inefficaces et inefficients de transfert de technologies plutôt qu'à l'absence totale de technologie appropriées. Il a été avancé que les Centres Nationaux de Recherche Agricole pourraient tirer un immense profit du stock mondial de technologies agricoles disponibles s'ils pouvaient développer une capacité effective de transfert de technologies avec l'appui d'un système bien contrôlé de recherche adaptative. Sans vouloir minimiser la recherche fondamentale, cette assertion souligne l'importance du transfert de technologies et de la capacité d'absoption et d'adaptation pour les pays à faibles ressources.

L'histoire montre que la science, appuyée par la recherche, l'information documentée, la communication et le commerce est un important stimulant pour l'innovation technologique. En Afrique, la recherche et le développement locaux ont toujours été considérés comme un préalable au transfert effectif de technologies.

La raison en est qu'une capacité de recherche et de développement bien planifiée et mise en oeuvre non seulement assure une base solide pour l'adaptation des technologies étrangères et nationales mais facilite également leur absoption et, fait plus important, leur exploitation par un développement plus poussé. Le transfert de technologies par delà les frontières nationales ou entre les secteurs industriels d'un même pays est un facteur essentiel de la croissance et du développement industriel et agricole. Il assure le mécanisme souhaité pour passer d'un stade de développement à un autre, ainsi que les moyens de forcer le changement. Il fournit les fonds nécessaires pour soutenir d'autres innovations technologiques tout en entraînant les effets compétitifs des techniques de plus faible coût.

Un Concept de Recherche et de Transfert de Technologies

Dans une analyse récente, Kaimowitz[8] et ses associés ont identifié des définitions conceptuelles clées pour l'étude du transfert de technologies. Selon eux, les termes "recherche et transfert de technologies" ont des significations à la fois fonctionnelles et institutionnelles. Dans leur utilisation fonctionnelle, ils décrivent certaines activités du processus de mise au point et de vulgarisation de technologies.

Dans le cas de la recherche, ces activités comprennent la découverte, le développement exploratoire et la consolidation de la technologie. La découverte est conçue comme le processus de collecte d'informations et/ou la recherche de relation entre des variables dont l'utilité spécifique est encore indéterminée. Souvent, l'on parle également de recherche fondamentale.

Le développement exploratoire est l'identification, l'exploration, la compréhension et le contrôle de l'interaction entre une technologie proposée et l'environnement physique, économique ou social dans lequel celle-ci sera finalement utilisée. On peut parler ici de recherche appliquée.

Le dictionnaire Webster[9] définit la technologie comme étant "une méthode technique permettant de réaliser un objectif pratique". Roling[10] définit la technologie comme étant "le logiciel et l'équipement disponibles pour contrôler l'environnement à des fins humaines. Le logiciel, selon lui, se compose de méthodes et de compétences, tandis que l'équipement est composé d'objets physiques comme les instruments, les matériels génétiques etc." Le développement de la technologie peut être basé sur l'avance de la science et de ce fait sur l'application des résultats de la recherche. Fresco[11] avance que la technologie représente le moyen par lequel les intrants sont transformés en extrants. Dans notre contexte, la technologie peut être conçue comme une idée, un produit, un intrant, une information ou une manière de faire les choses. Elle peut être physique, tangible ou abstraite. La consolidation de la technologie est le processus consistant à traduire les connaissances préalablement obtenues par la recherche fondamentale ou appliquée en prescriptions techniques pour le nouveau produit ou l'information et à l'intention de l'utilisateur final pour lequel la technologie sera appropriée. Les informations ou les nouveaux matériels sont présentés suivant un modèle qui sera utilisé à la livraison. Bien que la consolidation ait des aspects de recherche adaptative, elle va au delà. Elle comprend également tout le travail qui est nécessaire pour déterminer comment présenter et conditionner une technologie ainsi que pour identifier exactement qui peut désirer l'utiliser.

La production de technologies est le processus de production physique de matériels (intrants physiques ou matériels d'information) en quantité suffisante pour distribution à des clients cibles et de mise de ces matériels à la disposition de ceux qui sont chargés de véhiculer la technologie.

La délivrance de technologie est le stade où la technologie est en fait conditionnée, promue et distribuée. Elle se fait normalement par une multitude de canaux et une succession d'évèvements. Les groupes-cibles reçoivent les informations par bribes, informations dont certaines sont complémentaires et d'autres contradictoires, de diverses sources. Ils évaluent et intègrent ces informations au fil du temps dans leur processus de décision suivant l'acquisition et l'utilisation de la technologie.

Le suivi et l'évaluation de l'utilisation des technologies impliquent que l'on détermine si les utilisateurs finaux éventuels ont acquis les technologies proposées et ont décidé de les adopter, de les adapter ou de les rejeter totalement ou partiellement et qu'est-ce-qui justifie leurs décisions. Le processus de transfert de technologies couvre la production de technologies, la délivrance de technologies ainsi que le suivi et l'évaluation de leur utilisation.

Ces activités se mènent toutes ou au noins en grande partie et, simultanément au cours de la mise au point et de la délivrance d'une nouvelle technologie. Alors que le bon sens et la littérature font croire qu'il existe une progression logique entre ces activités (Mc Dermott[12]), il n'y a aucune raison de supposer que toutes les technologies doivent passer par un ensemble d'étapes donné dans une séquence chronologique. Par exemple, les travaux peuvent commencer par le développement exploratoire plutôt que par la découverte. Il peut aussi être techniquement bon que la nouvelle recherche soit entreprise avant une technologie déjà en voie de consolidation.

Les termes "recherche et transfert de technologies" servent également à indiquer les entités ou personnes spécialisées dans cette activité. C'est ainsi que nous avons les Centres de Recherche, les chercheurs, les Agents de Transfert de Technologies, etc.

La correspondance entre les deux utilisateurs est loin d'être parfaite. Différents groupes et institutions sont aux côtés des "chercheurs" impliqués dans la découverte, le développement exploratoire et la consolidation de technologies. Les chercheurs participent également à la production et à la diffusion de technologies ainsi qu'à d'autres activités du processus. Cette analyse a pour objectif essentiel d'attirer l'attention sur le processus de développement et de transfert de technologies dans l'abstrait et de nous détromper du fait que le procesus est simple et implique des personnes discrètes et des disciplines intervenant indépendamment les unes des autres.

Monsieur le Président,
Honorables chercheurs,
Mesdames et Messieurs,

Les concepts et idées que nous tenterons de comprendre et de discuter au cours de notre réunion sont un mélange de questions complexes nécessitant la réflexion et la participation des spécialistes des sciences naturelles, physiques, biologiques et sociales.

Il est prouvé que le degré inadmissiblement faible du développement technologique et l'inefficacité du processus de transfert de technologies en Afrique ne sont pas accidentels mais sont le résultat d'un effet cumulatif des politiques et actions de tous les acteurs du processus -gouvernements, donateurs, systèmes nationaux de recherche agricole, centres internationaux de recherche agricole, institution régionales et sous-régionales de recherche, universités et secteur privé. Ils partagent tous la responsabilité de la crise alimentaire à laquelle fait face l'Afrique. Il s'avère donc nécessaire de rechercher ensemble une nouvelle orientation concernant les problèmes d'augmentation de la production alimentaire et de relever le défi du 21^{e} siècle. Le processus sera évolutif et long et exigera de la persévérance et de la volonté pour réexaminer l'approche traditionnelle en matière de recherche agricole, de développement, de conditionnement et de transfert de technologies.

Le présent atelier a été organisé pour se pencher sur les deux questions "jumelles" mais intimement liées des Options Technologiques pour la Production de Cultures Vivrières et des Systèmes de Transfert de Technologies. J'espère que dans les débats sur les options technologiques il sera dûment tenu compte de la diminution des chances de l'Afrique d'acquérir des technologies exogènes nécessitant l'application de hauts niveaux d'intrants pour réussir. Cet atelier devrait avoir une vision de long terme pour le développement de technologies appropriées basées sur l'utilisation de faibles intrants par les paysans à faibles ressources. L'accent devrait être mis sur les cultures vivrières locales importantes dans l'alimentation de la population plutôt que sur les cultures exotiques.

L'objectif devrait être de maintenir des systèmes durables de production agricole qui soient respectueux de l'environnement plutôt que d'appliquer des systèmes qui exploitent l'environnement et entraînent la dégradation écologique. Vos travaux devraient être axés sur un processus optimum permettant d'améliorer et de réaliser les options technologiques les plus appropriées ainsi que sur le mécanisme clef requis pour soutenir leur mise en oeuvre au cours du 21è siècle.

Le défi du transfert de technologies consistant à faire face aux besoins de cultures vivrières durant le 21^{e} siècle est accentué par le faible niveau de la recherche sur le processus même de transfert de technologies. Implicitement, il semble que dans le sous-système du développement, de la diffusion et du transfert de technologies, le développement de technologies est considéré comme une activité de recherche et que le transfert de la technologie est le suivi pratique ou une pseudo-activité de recherche participant à la diffusion de technologies. De ce fait, l'évaluation de différentes approches au transfert de technologies a été normative et descriptive, dénuée d'une analyse de recherche critique et manquant donc d'une base scientifique prévoyant l'échec ou le succès. Par conséquent, la base de connaissances pour les liens recherche - transfert de technologies en patit. Au cours de cet atelier, vous discuterez des essais de vérification de la recherche en milieu paysan et évaluerez l'efficacité et les expériences des approches actuelles des services de vulgarisation et des systèmes de transfert de technologies. Je vous supplie d'être plus scientifiques, méthodiques et critiques dans votre évaluation pour être aussi objectifs que possible.

Monsieur le Président,
Mesdames et Messieurs.

La tâche qui sera la nôtre pendant ces quelques jours est une tâche difficile. Accomplissons-la avec tout le sérieux qu'elle mérite. Nos travaux devraient être considérés comme une importante contribution à la connaissance et à la pratique des méthodes permettant à l'Afrique de faire face au problème des cultures vivrières au cours du 21è siècle. Je ne doute pas qu'avec notre sagesse collective à tous, l'objectif de cet atelier sera atteint. En souhaitant plein succès à l'atelier, je vous remercie pour votre attention.

Intervention du Représentant du Ministre de l'Agriculture et des Ressources Animales à la Cérémonie de Clôture de l'Atelier Régional sur le transfert de technologie dans le domaine agricole

- Monsieur le Secrétaire Exécutif de la Commission Scientifique et Technique de l'OUA
- Monsieur le Représentant de la Banque Africaine de Développement
- Monsieur le Directeur Général de l'IDESSA, Président de cet Atelier
- Mesdames et Messieurs.

Le Ministre de l'Agriculture et des Ressources Animales, Monsieur Lambert Kouassi KONAN, aurait voulu être en personne à cette cérémonie. Mais ses importantes fonctions politiques le retiennent en ce moment précis dans le pays profond. Aussi, m'a-t-il demandé de le représenter.

Ce seminaire qui a réuni quatre jours durant, les Commités Techniques du Monde Agricole et de la Recherche Agronomique est la belle illustration de la solidarité entre nos pays ; il traduit également la prise en charge par les pays Africains eux-mêmes de leur développement agricole en particulier et de leur développement en général.

En effet la majeure partie des pays africains est préoccupée aujourd'hui par la satisfaction des besoins alimentaires de leurs populations. Ils ne peuvent compter que sur eux-mêmes. Pour cela, il faut une agriculture compétitive, productive qui n'est pas encore tout à fait au rendez-vous dans les pays africains en raison des faibles rendements à l'hectare enregistrés dans les différentes cultures agricoles.

Cette concertation a permis de confronter les expériences fort riches de chacun de ces pays. Au plan de la Technologie Agricole et de regarder les axes de réflexion et des programmes à mettre en oeuvre pour répondre à l'objectif de compétitivité de notre agriculture car le défi à relever à l'an 2000, c'est celui de l'alimentation face à une croissance démographique galopante.

Au regard des résultats fort encourageants de vos travaux, je ne peux que vous féliciter et vous souhaiter une volonté et une détermination à les mettre en oeuvre dans vos pays respectifs pour atteindre les objectifs énoncés ci-dessus avec le concours de tous : chercheurs, vulgarisateurs, sociétés d'encadrement et organismes financiers, producteurs et les femmes.

Aussi, je ne saurais terminer mon propos sans adresser mes vifs remerciements aux Organisateurs de cet atelier, notamment l'Organisation de l'Unité Africaine, la Banque Africaine de Développement et l'Union Européenne.

Tout en vous souhaitant un bon retour dans vos pays respectifs et dans vos familles, je déclare, au nom du Ministre de l'Agriculture et des Ressources Animales, clos l'Atelier Régional sur les options et systèmes de transfert de Technologies dans le domaine agricole.

Je vous remercie.

Speech by the Representative of the Minister of Agriculture and Animal Resources at the Closing Ceremony of the Regional Workshop on Agricultural Technology Transfer

- Honourable Executive Secretary of the OAU Scientific, Technical and Research Commission.
- Distinguished Representative of the African Development Bank.
- The Director general of IDESSA, chairman of this workshop.
- Ladies and gentlemen.

The Minister of Agriculture and Animal Resources would have liked to attend personally this meeting, but he is being held up right now by his important duties in the outside Abidjan. He has instructed me therefore to represent him.

This seminar which has gathered during four days the prominent scientists of the agricultural community and research is quite illustrative of the solidarity between our countries. It also demonstrates that African countries themselves are taking the responsibility for their agricultural development in particular and their development in general.

Most African countries, indeed, are concerned about meeting the food needs of their populations. They can only rely on themselves. This requires a competitive and productive agriculture which is not quite yet met in African countries because of the low yields per hectare recorded for the various crops.

This forum has made it possible to exchange the highly rich experiences of our countries in the area of agricultural technology and to define the thrusts of reflection and the programmes to be implemented in order to achieve the objective of competitivity of our agriculture since the challenge to be faced by the year 2000 is meeting food requirements for a rapidly growing population.

In view of the highly encouraging results of your deliberations, I cannot but congratulate you and wish you the required will and determination to implement them in your respective countries so as to attain the above mentioned objectives with the support of everybody: researchers, extensionists, training and supervision companies, funding agencies, producers and women.

I could not conclude my address without expressing my deep gratitude to the organizers of this workshop, particularly the Organization of African Unity, the African Development Bank and the European Union.

While wishing your a safe journey back to your respective countries and families. I declare on behalf of the Minister of Agriculture and Animal Resources, the "Regional Workshop on Technology Option and Transfer Systems in Agriculture" closed.

Thank you.

Closing Remarks by Professor J.A. Ekpere

Executive Secretary Scientific, Technical and Research Commission of the Organisation of African Unity (OAU/STRC) Lagos, Nigeria

Mr. Chairman,
Mr. Kouizia Denis, Director of Agro-Industries, Côte d'Ivoire representing the Honourable Minister of Agriculture,
International Coordinator, SAFGRAD,
Distinguished Agricultural Research Scientists,
Ladies and Gentlemen,

This workshop has been organized with due recognition of the harsh environment for the semi-arid agriculture, as well as, of the importance of food grains in the dietary requirements of millions of African households. The holistic nature of the workshop has been that, the entire spectrum of agricultural research, technology development, processing, packaging and transfer have been discussed. The need for policy reforms, and to address gender issues were considered.

On-behalf of OAU/STRC in general and the participants of this workshop in particular I take this opportunity to express our appreciation to the Government and people of Côte d'Ivoire for co-hosting this workshop. Our sincere gratitude goes to the African Development Bank, The European Union, the Organization of African Unity and CTA for their financial assistance in enabling several participants to attend this workshop.

Finally, I would also like to thank the chair persons, rapporteurs, the secretariat and interpreters for their excellent service and for making this workshop very successful.

Allocution de Clôture du Professeur J. A. EKPERE,

Secrétaire Exécutif de la Commission Scientifique, Technique et de la Recherche de l'Organisation de l'Unité Africaine (OUA/CSTR) Lagos, Nigeria.

Monsieur le Président,
Monsieur KOUIZIA Denis, Directeur des Agro-industries de
Côte d'Ivoire représentant S.E. M. le Ministre de l'Agriculture de Côte d'Ivoire,
Monsieur le Coordinateur International du SAFGRAD,
Messieurs les Spécialistes de la Recherche Agricole,
Mesdames et Messieurs.

C'est en pleine connaissance des rigueurs de l'environnement de l'agriculture semi-aride ainsi que de l'importance des cultures vivrières dans la satisfaction des besoins alimentaires de millions de ménages africains qu'a été organisé le présent atelier. Le caractère global de l'atelier s'est traduit par le fait que toutes les questions relatives à la recherche agricole, à la mise au point de technologies, à la transformation, à l'emballage des produits et au transfert de technologies ont été abordées. La nécessité de procéder à des réformes politiques et de traiter les questions de genre a été soulignée.

Au nom de l'OUA/CSTR en général, et des participants à cet atelier en particulier, je saisis l'occasion pour exprimer nos sincères remerciements au Gouvernement et au peuple de Côte d'Ivoire pour avoir abrité cet atelier. Notre sincère gratitude s'adresse également à la Banque Africaine de Développement, à l'Union Européenne, à l'Organisation de l'Unité Africaine et à la CTA pour leur assistance financière qui a permis à plusieurs participants d'être présents à cet atelier.

Enfin, je voudrais aussi remercier les présidents de séance, les rapporteurs, le secrétariat et les interprètes pour les excellents services qu'ils ont rendus en vue du très grand succès de l'atelier.

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TECHNOLOGY OPTIONS FOR SUSTAINABLE AGRICULTURAL PRODUCTION IN SUB-SAHARAN AFRICA

Bezuneh, Taye

OUA-CSTR - SAFGRAD