

PABRA Millennium Workshop

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The sales value alone of this crop now exceeds US\$ 450 million, with much of it crossing national borders to meet urban demand, while 50% of production is still retained for domestic consumption. We have set ourselves the task, during the next five-year period, of reaching at least two million rural households (about 10 million people) in at least 12 countries. With more than 100 million people in Africa's urban and rural areas currently consuming beans, this target should be considered conservative. We cannot be complacent, but I do believe this is an exciting time for those committed to development who are prepared to adjust to changing times!

Roger Kirkby
PABRA Coordinator

SESSION 1
INTRODUCTION AND WELCOME

INTRODUCTION

AN OVERVIEW OF THE PAN-AFRICA BEAN RESEARCH ALLIANCE

Roger Kirkby

BACKGROUND

First of all, I would like to express, on behalf of all partners in the Pan-Africa Bean Research Alliance (PABRA), our appreciation to Tanzania and to the Director of Selian Agricultural Research Institute for hosting this important event.

It was, first and foremost, intended as a celebration: of what we had achieved together in the past 10 years, of the benefits of good science for real development, of the value of partnerships, and above all, of the impact on hundreds of thousands lives in central, eastern, and southern Africa. The workshop also proved to be an opportunity for reflection upon what we still needed to do, what we could offer to others by way of examples and lessons, and in what ways we needed to change to achieve new objectives.

However, I would like to pause and remember a number of former colleagues and close collaborators who contributed to the overall effort but have passed away during this period. I am sure I speak for all of us in conveying our deepest condolences to the family of Mary Mutetikka, economist in the national programme of Uganda, who passed away earlier this month. We also lost, during the past few years, two national coordinators of bean research who had been often with us on occasions such as this: Epimaki Koinange of Tanzania and Gaspar Gasana of Rwanda.

The Pan-Africa Bean Research Alliance (PABRA) is a partnership between three autonomous implementational units: the Eastern and Central Africa Bean Research Network (ECABREN), the Southern Africa Bean Research Network (SABRN), and the International Center for Tropical Agriculture (CIAT). The two networks respond to separate sub-regional organisations of national agricultural research systems (NARS), and PABRA serves to bring together these networks for joint planning on shared problems and activities, and provides a forum for transparent planning and reporting of activities undertaken by the international centre in support of the networks and their members.

PABRA as such did not exist 10 years ago. At that time there were three networks (the Great Lakes and Eastern Africa then being distinct), supported by somewhat separate regional teams from CIAT, with any coordination among them being centralised in CIAT. The current alignment evolved during the period 1992-95 in response to strengthening national systems, reduced funding for individual regions and the opportunity to provide more cost-effective international centre support from a smaller, unified African team. Over the same period, the networks became practically autonomous of CIAT, with regionally recruited coordinators, and policy and oversight being provided by the sub-regional organisations—the Association for Strengthening of Agricultural Research in Eastern and Central Africa (ASARECA) and the Southern Africa Centre for Coordination of Agricultural Research (SACCAR, now reorganised as a Sector Coordinating Unit for SADC).

AN EVOLVING AGENDA

Regional collaboration around shared problems, joint priority-setting, and agreed-upon division of responsibilities has been a strong feature of bean research in Africa since 1986. Even before PABRA, we held a pan-African workshop in 1990 to mark the new decade and report progress (Smithson, 1990). The nature of our regional collaboration, however, has changed in many respects. Even our objectives have evolved: from concern with increasing productivity of the crop to contributing to poverty alleviation among those who grow and consume it. We now more explicitly address food security, income generation, and the health of the rural poor, while maintaining special concerns for reaching women farmers as the crop's main producers, and improving environmental sustainability.

The portfolio of network sub-projects has remained at the centre of regional bean collaboration throughout the last decade. Information exchange and training activities, which in the 1980s made enormous inroads into what had been a large vacuum with broad demands, have gradually become more focussed upon serving the needs and outputs of network research. And some of the best sub-projects started assisting other countries.

CIAT's role has evolved considerably. Training activities have become much more focussed and specialised, as the networks developed the capacity to carry out their own basic training. Similarly, gap-filling in national programmes is no longer considered an appropriate role for an international centre. Strategic research—the production of international public goods that address key cross-situational problems—has become a predominant activity, on topics where agreement exists on comparative advantage. In thinking globally while acting locally, CIAT's strategy is to carry out virtually all strategic research in collaboration with national partners. Principles of partnership are applied throughout PABRA: collaborative advantage, mutual trust, and the giving and sharing of credit. The closeness of the partnerships is reflected in the fact that all regional staff are hosted by/in NARS research centres and that CIAT has been requested by NARS directors to maintain this type of staffing pattern instead of moving into separate facilities dedicated to international centres.

At our first pan-African synthesis workshop in 1990, we reviewed what I now refer to as the first-generation activities. The main emphases at that time had been (1) farmer surveys and feedback to reorient bean research priorities towards farmers' problems, resources, and preferences, (2) basic training in station and on-farm research methods for scientists and technicians, and (3) development of new technologies, mostly varieties.

By the early 1990s, a second wave of activities had taken off: (1) many more variety releases, with a wider range of attributes, by almost all national programmes, (2) a more demand-led approach to developing and disseminating technologies, including (3) more complex technologies related to integrated pest management and improving soil fertility.

ACHIEVING IMPACT

In 1990 we could not talk about impact. Shortly thereafter, however, significant numbers of farmers were adopting new bean varieties—initially in the Great Lakes region where participatory research and seed system studies had taken off early, later in Eastern Africa, and more recently in Southern Africa.

Steadily rising rates of varietal release by national programmes were evidence of the returns to investment in training, in streamlining varietal development procedures, and in assuring increased access to germplasm with the required traits for African conditions. A record 64 bean variety releases were made by 10 member countries in the period 1998-2000. Approximately 51% of this latest set of varieties were bred by CIAT, 20% were introduced from other African countries or from the CIAT germplasm bank, 11% were locally bred, and 18% were selected locally from farmers' varieties. This shows a doubling in the rate of national programmes' output over the previous three years, a growing reliance upon the products of breeding programmes (still mostly at CIAT) because the global reservoir of farmers' varieties is producing fewer easy gains than in earlier years, and a modest but significant increase in output from local breeding efforts by a few countries (Ethiopia, South Africa, and Tanzania). New varieties combining resistance to serious African problems (e.g., stem maggot or low-phosphorus soils) with other necessary traits were released for the first time.

In this workshop, we heard several of the success stories from bean research and development, both from technologies developed through PABRA partnerships and from the application of better methods for achieving impact with farmers. But time did not permit us to include all the success stories that could have been mentioned. For example, just in the arena of the new high-yielding climbing beans that emerged as our first success story in the early 1990s, there were unfortunately no specific reports on:

- how great the spillover of research from ISAR Rwanda to farmers elsewhere in eastern Africa has been, with one of the smallest NARS still today providing technologies that are enabling the largest NARS in the region to create new impact
- how scientists at KARI Embu achieved probably the fastest and most cost-effective adoption of climbing beans, through handing out 10 seeds per farmer and reaching 1700 farmers within two years of introducing the technology
- how NGOs have successfully used climbing beans and their response to staking as an incentive for farmers to invest in agroforestry for soil fertility improvement/conservation

We did hear something, however, of several other success stories: new bush bean varieties that surpassed the better-known impact achieved with climbing beans; IPM; green manures; methodological advances in seed systems and participatory research; and more. The networks are demand-led, and the papers included here reflect the enthusiasms of those who offered abstracts, tempered only by some attempt to maintain regional and thematic balance. We regret that not all papers offered could be included.

CURRENT CHALLENGES

I believe we have now entered a third generation of PABRA activities, focused on recording wider and deeper impact. We start from the recognition that consumer demand is unsatisfied and rising, several serious constraints remain technically difficult, research results have not reached everyone they could, and the output of bean research needs integrating with the output from other actors in order to achieve our vision of an ‘upward spiral’ out of poverty.

Interestingly, Rwandan agriculture remains a useful pointer to regional trends—no doubt due to its very intensive nature—and a source of potential solutions for the region. Rwanda and, later, Malawi have provided innovative ways that proved key to disseminating and creating demand for seed of new varieties. Uganda has developed some of the region’s first entrepreneurial seed-producing groups. D.R. Congo, Ethiopia, and Tanzania are pioneering the incorporation of participatory bean breeding into their programmes.

We have learned a great deal from successful bean research and development about how to ‘scale up’ new technologies and processes. The networks have clearly articulated frameworks that are now more oriented to market demands. We, who pioneered much of the participatory research as well as participatory extension tools (decision guides) now practiced by others, have the challenge to strengthen the decision-making capacities of farmers and communities so that they invest the better diets and income derived from bean innovations into agricultural intensification and other enterprises. There is a need to improve the links between the informal and formal research systems in the interest of a more financially sustainable integrated system. We are publicising and adapting our PABRA experiences and lessons beyond the bean crop—where necessary by actively influencing the work of others. A good example was the effect of successful bean network approaches (multiple variety releases that offer options to farmers and the use of informal seed systems to achieve impact) upon the harmonisation of seed policies in the ASARECA region.

Stronger national programmes are now serving the networks as sources of expertise: Kenya and Malawi for bean breeding, South Africa for disease resistance, D.R. Congo for tolerance to soil fertility constraints, Madagascar in participatory research methods for improved agro-ecosystem management.

As national programmes and networks have developed, the role of CIAT in the Alliance has also evolved further, as we heard from the presentations. CIAT’s former role in bean breeding within Africa has devolved to regional breeders in the networks, with specific regional responsibilities shared among national programmes. CIAT supports these decentralised yet highly coordinated breeding efforts by supplying segregating populations and, increasingly, parental materials for specific traits on request—from CIAT Headquarters or from regional pathology and IPM specialists in the cases of the more intransigent problems of root rot and stem maggot. CIAT has also phased out its production agronomy work—with responsibility having passed to national programmes and their regional resource persons—but works with national programmes on some strategic aspects of intensifying agricultural systems within the African Highlands Initiative (AHI).

Our revised PABRA goal emphasises the need to achieve still wider impact and to make this sustainable by enhancing the capacity of rural communities in eastern, central, and southern Africa to manage their own livelihoods. The partners in PABRA agreed to a detailed framework that aimed to produce the following (summarised) outputs in the next five years:

- improved household food security and nutrition for women, children, and the rural poor
- more income from beans
- pilot communities becoming better managers of their resources
- wider impact across Africa
- consolidation of the institutional base of PABRA

New skills will be required to address new priorities in the new decade. Bean varieties need to be improved for micronutrient content. More complex technologies (for IPM and soil fertility) are now reaching farmers

but need to pass beyond the pilot stage through better understanding of the approaches necessary to achieving widespread adoption and impact with different categories of farmers. Rukuni (2000) argues that Africa, in emphasising the development of the 'hard' sciences, has under-invested in 'people skills' for a farmer orientation, a complex area that warrants experienced researchers yet generally occupies the newest recruits. As we in PABRA have probably done more than most to demonstrate the importance of incorporating social science skills into agricultural research, we have a responsibility to continue showing the way forward.

Fostering partnerships with farmer organisations capable of taking on more responsibilities for innovative and adaptive research, and with private-sector seed companies where they exist, will be needed if researchers in the public sector are to continue to supply critical technologies and ideas on reducing budgets. These partnerships appear increasingly feasible, as various papers this week will show. At the same time we must also recognise that some local research centres, many NGOs and a few of the emerging private-sector organisations appear not to be involved in the networks, despite increasing connectivity that enables all actors to become more proactive. This is a challenge that national programmes can more easily confront as governments decentralise and encourage wider participation.

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PABRA MILLENNIUM WORKSHOP GUEST OF HONOUR'S SPEECH

**A. S. S. Mbwana, ZDRD (NZ) Tanzania
On Behalf of J. M. Haki, DRD**

**MR. CHAIRMAN/MADAM CHAIRPERSON,
COLLEAGUES, LADIES AND GENTLEMEN:**

It is my pleasure to be with you today as you review your achievements and chart your future direction in your agricultural research for development. I said 'agricultural research' because I understand that even though your focus has been on beans, the bean crop in this region is almost always grown in combination with other crops, and therefore what you do on beans spreads to the entire farming system.

The role of beans in rural household food security and the economy

Beans have often been described as the 'Meat of the Poor' and in eastern and southern Africa they are recognised as the second most important source of human dietary protein and the third most important source of calories. The eastern and southern Africa region has the second highest production after Latin America, some 25% of global production. The region also has the highest per capita consumption of beans, about 50 kg/person per year, but in parts of western Kenya, I understand that consumption may exceed 66 kg/person per year. Beans contribute as much as 60% of the dietary protein in countries such as Rwanda and Burundi. They are highly valued by the poor because all parts of the plant are consumed: the leaves are used as spinach and the grains are eaten fresh or dried, while the haulm (stems and pod shells) is fed to livestock. Although beans are grown largely for subsistence, and mainly by women farmers, about 40% of the total production in Africa is marketed, at an average annual value of USD\$452 million, according to a recent publication (Wortmann et al., 1999). The income from such sales is used for household needs and to pay for children's education. In northern Tanzania, beans are a commercial crop: several large-scale producers export a substantial part of their produce across borders. ASARECA rates beans as the second most important food crop in the region.

I am told that in Rwanda one often sees oceans of climbing beans in the Ruhengeri and other areas and that this technology is spreading to other parts of the region. Climbing beans produce more than three times the average yield of the bush types, and this is perhaps a good way of meeting the demand for beans, especially in areas where land is limited. In Tanzania, the climbing bean technology is just beginning but it is my hope that together with other countries, we can learn from Rwanda in the true spirit of networking.

Bean production constraints

The crop, however, is grown under difficult conditions, such as marginal lands with infertile soils, prone to drought, pests, and diseases. Farmers often do not have access to quality seeds and when they succeed in producing surpluses, they have difficulty accessing markets, and are therefore unable to extract sufficient profits from their labour.

Impacts of bean research and development

Mr. Chairman, I understand that the bean networks and CIAT have, together; made substantial contributions to addressing these constraints and hopefully these will be the focus of the discussions this week.

I know that new varieties released through the Tanzania Bean Program are many and several of them—the 'Lyamungu' varieties, the 'Selian' varieties, 'JESCA', and several others in the Southern Highlands—have been well adopted and are having an impact on the lives of farmers, traders, consumers, and the general economy. I am also aware of IPM strategies that have been adopted by farmers. Such farmers have initiated a farmer-to-farmer dissemination programme to reach the entire bean-production community in the northern zone. I am told there are many similar achievements in the other networks and that some of your technologies have even reached far eastern Asia. You should be very proud of them! I congratulate you on that significant contribution.

The challenges ahead

While you take pride in your past achievements, you should also look at the challenges ahead; your work is not finished yet.

- I am aware of many other groups that share your ideals and could join in partnership with you to reach your goals. I challenge you to seek them and ensure sustainable, complementary, and synergistic linkages.
- I would like to challenge you to re-examine the entire production-to-market continuum. Identify all profit dopers. If you can succeed in arresting them, your work will be more meaningful as farmers make more income from beans.
- I would like also to challenge you to look at community empowerment and development. This will enable the people you serve to contribute to your development agenda in ways that will be more meaningful to them and which will create greater impact.
- My last challenge to you is that you should ensure that the technologies that you generate with your partners lead to sustainable production environments.

Mr. Chairman, I am told that you will be taking some time off to see some of the farm activities in Arumeru and Hai and that this trip will take you through some of the important bean-producing areas in the northern zone of Tanzania. The farmers are hardworking and will benefit from your discussions with them, but I am sure that you will also be able to learn some things from their indigenous knowledge.

Arusha is the hub of tourism in Tanzania, and if any of you can afford the time, I will encourage you to visit some of our parks. Arusha, Tarangire, and Manyara National Parks are very close by and can be accessed within a day.

Mr. Chairman, I am glad that this workshop has brought many important researchers together in Arusha to deliberate on such an important issue: 'Bean Research for Development'. I am sure that your deliberations will lead to strategies to expand your achievements and create greater impact on farmers in the region and the world in general.

I wish you a successful workshop and declare that your workshop is officially open. Thank you for your attention.

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SESSION 2
CROP IMPROVEMENT

BREEDING BEANS FOR SMALLHOLDER FARMERS IN EASTERN, CENTRAL, AND SOUTHERN AFRICA: CONSTRAINTS, ACHIEVEMENTS, AND POTENTIAL

P. M. Kimani, R. Buruchara, K. Ampofo, M. Pyndji, R. M. Chirwa, and R. Kirkby

ABSTRACT

Serious declines in food security and income in sub-Saharan Africa over the past two decades have resulted in widespread poverty and malnutrition, especially among resource-poor smallholders and the urban poor. The common bean is a major part of their food requirements and source of income, but there have been declines in bean productivity, attributable to a number of factors and estimated at nearly 3,000,000 t per year. In the last 16 years, the Pan-African Bean Research Alliance (PABRA) together with NARS partners, farmers, NGOs, and other stakeholders have sought to overcome these constraints by breeding high-yielding, disease- and pest-resistant cultivars adapted to poor soils, with characteristics acceptable for domestic and export markets, and seed production and delivery systems for smallholder producers, among other things. A record 188 distinct varieties have been released and have contributed significantly to improvements in the livelihoods of resource-poor rural communities through increased availability of food and household income, savings in cooking time, reduced wood fuel consumption, gender equity, and empowerment of women and other vulnerable groups. Adoption rates of up to 100% indicate that accelerated dissemination and adoption of improved bean cultivars can significantly contribute to improving food security, household income, and poverty alleviation, especially for the most vulnerable groups.

RÉSUMÉ

La sécurité alimentaire et les revenus ont connu au cours de ces deux dernières décennies en Afrique subsaharienne une baisse importante qui a entraîné une aggravation de la pauvreté et de la malnutrition, tout particulièrement parmi les petits exploitants pauvres et les citadins démunis. Le haricot commun, qui répond pour une part essentielle aux besoins alimentaires de cette population pauvre et/ou constitue une source de revenus, a connu une baisse de la productivité, imputable à différents facteurs et estimée à près de 3 000 000 tonnes par an. Au cours des 16 dernières années, l'Alliance panafricaine pour la recherche sur le haricot (PABRA) en partenariat avec des Systèmes nationaux de recherche agricole (SNRA), des agriculteurs, des ONG et d'autres parties prenantes, a cherché à surmonter ces contraintes en sélectionnant des cultivars à haut rendement, résistants aux maladies et aux ravageurs, adaptés aux sols peu fertiles et dotés entre autres de caractéristiques adaptées aux marchés intérieurs et d'exportation ainsi qu'aux systèmes de production et de diffusion semencières destinés aux petits exploitants. L'introduction d'une quantité record de 188 variétés distinctes a contribué à améliorer de manière significative les moyens de subsistance des communautés rurales démunies grâce à une augmentation des quantités de nourriture disponible et des revenus des ménages, un temps de cuisson plus rapide et une consommation réduite du bois de combustion. Ceci a également contribué à améliorer l'égalité entre les sexes et les chances offertes aux femmes et aux autres groupes vulnérables. Des taux d'adoption pouvant aller jusqu'à 100 % indiquent qu'une diffusion et une adoption accélérées des cultivars améliorés de haricots peuvent contribuer de manière significative à l'amélioration de la sécurité alimentaire, à l'augmentation des revenus des ménages et à la réduction de la pauvreté, spécialement pour les groupes les plus vulnérables.

INTRODUCTION

As the new millennium starts, food security and the alleviation of poverty are high on the development agenda in many countries in Africa. This is because productivity failed to keep pace with demand in the last two decades of the twentieth century due to a rapid growth in population. Available data indicate that Africa was the only continent with decreasing per capita food production in that time (World Bank, 1996). Because

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of low agricultural production and limited alternative sources of income, there is extreme poverty (with many people subsisting on less than one US dollar or Kshs 76 per day), widespread malnutrition, and massive environmental degradation. It is further predicted that between 1997 and 2020, Africa's population will more than double to over 1.1 billion people (Quinones et al., 1997). If present trends continue, food insecurity, malnutrition, and resource degradation will increase. Africa will need to import between 50 and 70 million tonnes of foodstuffs per year (mainly cereal grains) to meet the demands of the increased population, which today has the highest growth rate in the world. Quinones et al. (1997) believe that Africa will not have enough economic resources to procure such a huge volume of food on a commercial basis, nor will the international community be willing to provide it as concessional sales or food aid. To mitigate against this prediction, researchers, farmers, development agents, governments, and other partners will have to maintain a concerted effort in improving gains made in productivity, particularly of cereals and root crops (as sources of energy) and grain legumes (as major sources of protein and micronutrients).

The common bean (*Phaseolus vulgaris* L.), probably the most important grain legume in Africa, is grown on an estimated 3.7 million ha every year and provides food and income to at least 100 million people in eastern, central, and southern Africa. In this region, the bean is a major staple, providing the second most important source of human dietary protein and the third most important source of calories (Pachico, 1993). Per capita consumption in this region is perhaps the highest in the world, exceeding 50 kg in eastern and southern Africa and reaching over 66 kg in the densely populated Kisii districts in Kenya (Jaetzold and Schmidt, 1983). In Rwanda, beans provide 60% of the dietary protein (MINIPLAN, 1988), and in many countries in the region, beans are a principal source of dietary protein for the urban poor.

BEAN CULTIVATION

Beans are primarily grown as a food crop and to generate income by smallholder, resource-poor farmers in eastern and central Africa, in holdings that rarely exceed 1.5 hectares. They are grown in pure stands or in association with maize, bananas, or root or tuber crops, and in recent years, between rows of fruit crops and coffee, especially in the early establishment phase of these traditional cash crops. About 22% of the production area is sole-cropped, 43% is in association with maize, 15% with bananas, 13% with root and tuber crops, and 7% with other crops (Wortmann et al., 1998a). In southern Africa, beans are either grown in pure stands (42%) or in association with maize (47%), or, to a lesser extent, with root crops (6%) or other crops (5%). Production is mainly rainfed in most of east, central and southern Africa, while beans are grown as an irrigated crop in Mauritius, the Nile Valley of Sudan, along the Niger River in Mali, and in most of northern Africa. In lowland areas of Madagascar, Malawi, Mozambique, and DR Congo, beans are sown after another crop in order to use residual moisture and to take advantage of lower temperatures during the winter months. Production is generally one sole crop per year.

Production areas

An estimated area of 3,741,000 ha is sown annually to beans in Africa (Wortmann, et al, 1998a), in all five geographical areas: eastern, central, southern, western, and northern. Much of the production is at elevations from 1000 m to 1800 m above sea level (masl) (Figure 1). The eastern African highlands account for 38% of bean production in Africa; mid-altitude zones account for 24%. Southern Africa accounts for about 32% of bean production in Africa, with about 518,000 ha in areas up to 1500 masl. Western Africa is estimated to have 135,000 ha of beans. Lowland bean production (below 1000 masl) is geographically dispersed in eastern, northern, and southern Africa and accounts for 203,000 ha.

Bean types produced

There are four categories of bean grown in Africa:

- bush bean, grown for its dry seeds
- tall climbing bean, also grown for its dry seeds
- snap bush bean, grown for its succulent immature pods used as a vegetable
- climbing snap bean, including the runner beans, grown for immature pods used as a vegetable

The leaves of bush and climbing types are also used as a vegetable in some systems, and the haulms after harvest are fed to livestock as a high-protein feed in areas like Ethiopia's Rift Valley. The relative importance

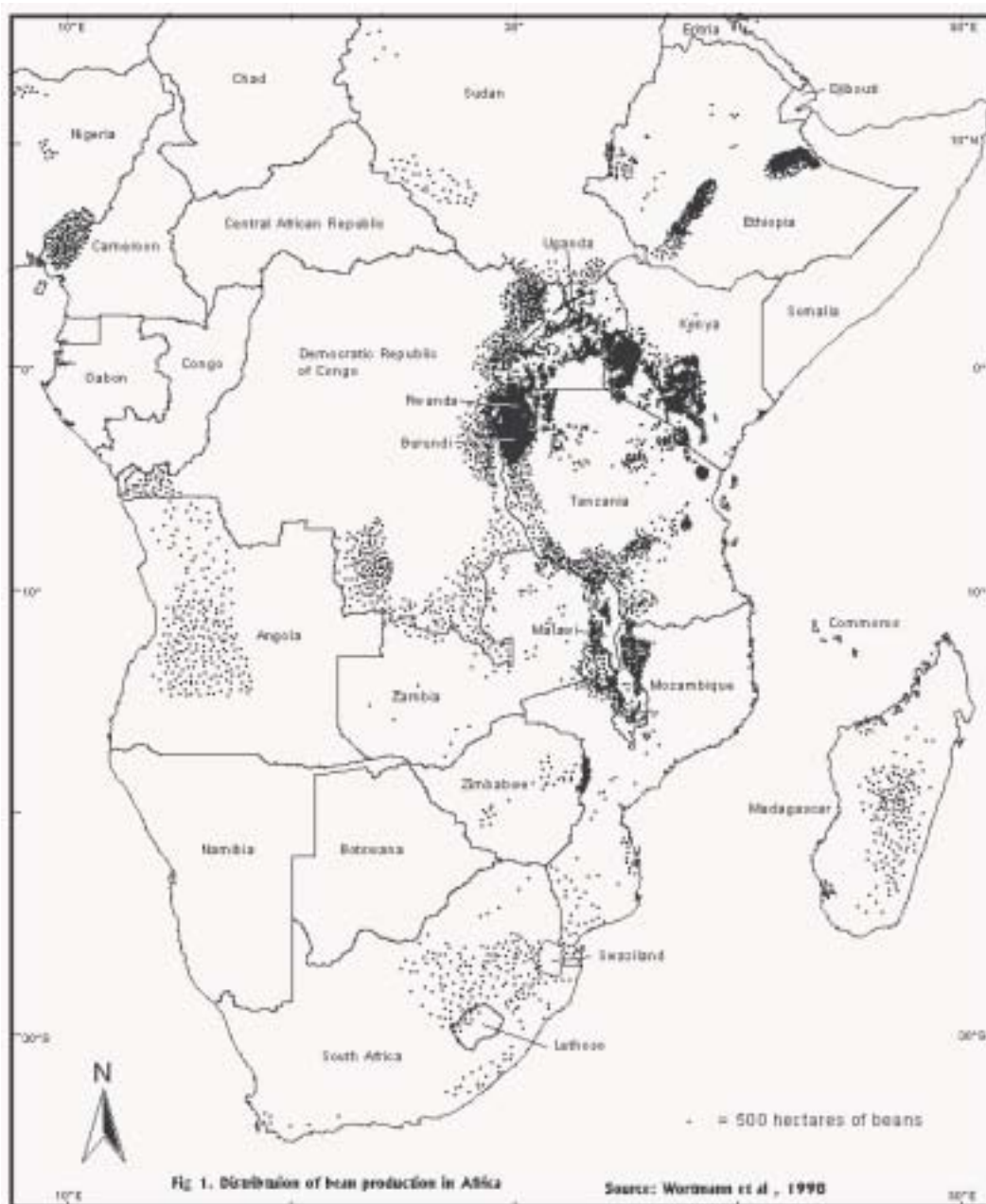


Figure 1. Distribution of bean production in Africa

in terms of area under production is listed above but may differ from country to country. For example, in Kenya snap bush beans rank higher than climbing beans.

Diversity

Typically, three to six easily distinguished cultivars account for 95% of the production in a bean-producing community. Diversity is greatest in the Great Lakes Region and southwest Uganda, where beans are produced, marketed, and consumed as complex varietal mixtures (Wortmann et al., 1998a). In Rwanda, mixtures average 11 components and may contain as many as 27 (Lamb and Hardman, 1985). Farmers maintain and adjust mixtures according to growing conditions (Voss, 1992). In parts of Malawi, Mozambique, Tanzania, and Uganda, production in mixtures is still important even though market sales are by variety. Kenya typifies those countries that have become relatively commercial in their bean production. Production is mainly by variety. Urban market forces have caused farmers to specialise on a few varieties and many have been abandoned, although on average, farmers still grow four varieties in different proportions.

CONSTRAINTS TO PRODUCTIVITY

Bean producers are faced with several problems that reduce the productivity and commercialisation of this crop, contributing to food insecurity, unavailability of low-cost protein, and low incomes for both rural and urban populations in Africa. These problems can be grouped into four categories: those associated with (1) production, (2) seed delivery systems, (3) marketing, and (4) agricultural research and extension.

Production problems

These include low yields, which result in perennial food shortages and lack of surplus for cash. Although yields are variable across countries and regions, they generally vary from 200 kg/ha in less favourable environments to 700 kg/ha in more favourable environments when grown in pure stands, and about half of this when intercropped. Several biotic and abiotic factors contribute to low bean yields. Biotic constraints include diseases and pests, varieties with low yield potential, and susceptibility to diseases and pests. Main biotic constraints in eastern Africa, in descending order of importance are angular leaf spot (*Phaeosariopsis griseola*), anthracnose (*Colletotrichum lindemuthianum*), bean stem maggot (BSM) (*Ophiomyia* spp.), bruchids (*Zabrotes subfasciatus* [Boheman] and *Acanthoscelides obtectus*), root rot, common bacterial blight (CBB), aphids, rust, and bean common mosaic virus. In southern Africa, the major biotic constraints include (in descending order of importance) BSM, angular leaf spot, bruchids, rust, anthracnose, and CBB. The losses attributed to these constraints are shown in table 1.

Table 1. Losses to Bean Production in Africa, Ranked in Descending Order of Importance, by Constraint

Constraint	Eastern and Central Africa	Southern Africa	Sub-Saharan Africa
	Losses (t/year)		
Biotic			
Angular leaf spot	281,300	93,500	384,200
Anthracnose	247,400	69,800	328,000
Bean stem maggot	194,400	96,400	297,100
Bruchids	163,000	77,600	245,600
Root rots	179,800	31,000	221,100
Common bacterial blight	145,900	69,800	220,400
Aphids	136,300	58,900	196,900
Rust	118,700	72,400	191,400
Bean common mosaic	144,600	29,900	184,200
Abiotic			
Drought	291,200	94,600	396,000
N deficiency	263,600	125,200	389,900
P deficiency	234,200	120,400	355,900
Exchangeable bases	152,700	65,800	220,000
Al/Mn toxicity	97,500	60,300	163,900

The severity and incidence of these diseases vary with seasons and locations, but the top five (listed above) are widespread and cause serious yield losses. The management of these diseases is further constrained by pathogenic variation for most of them. Economic losses are aggravated by farmers sowing late to avoid susceptible varieties being attacked by foliar diseases (Wortmann et al., 1998a). At the regional and continental levels, angular leaf spot, anthracnose, and CBB are the main constraints to bean production. A complex of root-rot species is increasing in importance in eastern and central Africa and is devastating some areas of intensive bean production. Available data indicate that root rot tends to be more severe in areas with low soil pH, cooler temperatures, low K, low soil fertility, and intensive bean cultivation where crop rotation is not feasible because of declining plot sizes.

BSM is the insect of greatest concern. It is widespread and especially serious for late-planted crops and when conditions for seedling growth are not favourable. Bruchids cause heavy post-harvest losses and, consequently, heavy losses of profit because farmers are obliged to sell their beans immediately after harvest

when prices are low. Bruchids are moderately important in all areas, but highly important under warm conditions with a single growing season. Aphids are widespread and are vectors for bean common mosaic virus. Other pests contributing to low yields include thrips, pod borers and suckers (*Helicoverpa*, *Maruca* and *Clavigralla*), foliage beetles (*Ootheca* spp.), whiteflies (*Bemisia tabacci*), and pollen and blister beetles.

The most important abiotic constraints are soil related. In order of decreasing importance, they are N deficiency, P deficiency, low exchangeable bases, and soil moisture deficits, which may occur early, mid, or late in the season (see table 1). P is the most frequently deficient nutrient and supply is low in 65% and 80% of the bean-production areas of eastern and southern Africa. Availability of soil N is lower in southern Africa, being low on 60% of the bean production areas and moderately low on 30%. In eastern Africa, N is low on 50% of the production areas.

Deficiency of bases is a major constraint to bean production. Potassium is moderately deficient on 45%–50% of the area in both eastern and southern Africa. Aluminium and manganese toxicity are constraints of moderate importance. Wortmann et al. (1998a) estimated that they cause losses of 200 kg/ha for a sole crop if soil pH is 4.5 to 5.0 and 100 kg/ha if soil pH is 5.0 to 5.5. In the semi-arid regions, bean productivity is constrained by moisture deficits. Eastern Kenya and eastern Transvaal are major areas of bean production where moisture deficits are frequent and severe. Other areas are parts of northern Tanzania, the Kasese area of Uganda, and parts of the Hararge Highlands and Rift Valley of Ethiopia.

Other factors also affect production. While farmers generally recognise the need to carry out such cultural practices as timely planting, fertiliser and manure application, weeding, crop protection in the field and after harvesting, and timely harvesting and storage, they are prevented by constraints including inadequate labour (because children are in school or employed elsewhere), inability to hire labour, and lack of cash to buy fertilisers, chemicals, and spray equipment or to construct proper storage structures. In other situations, farmers lack know-how on appropriate production and post-harvest management practices.

Many farmers still grow their traditional bean varieties and other varieties released in the 1970s, which are susceptible to diseases and pests and have low yield potential. These varieties also lack tolerance to soils deficient in macronutrients and with toxic levels of Al and Mn. Because of continuous cultivation without replenishment of nutrients either by applying manure or fertilisers, fertility has continued to decline and is further worsened by a build-up of soil-borne diseases, such as root rot and *Fusarium* wilt, and pests, such as cut worms. For example, between 1991 to 1993 farmers in the Kakamega and Vihiga Districts of western Kenya reported extremely poor performance, even with adequate rainfall, due to a serious build-up of root rot, BSM, and low soil fertility (Nekesa et al., 1998). Indeed, some farmers stopped planting beans.

Seed delivery constraints

Improved bean cultivars are likely to have minimal impact if an efficient and reliable seed delivery system is not in place. Many farmers in the region do not have access to quality bean seed, especially of the improved varieties, and have to rely on their farm-saved seeds. This is attributed to inadequate seed distribution networks, where they exist. Due to the poor infrastructure, seeds reach the farmers late in the season or do not reach them at all. In other cases, the quantities are inadequate and of poor quality. In areas where seeds are readily available in local shops and markets, farmers may not have adequate resources to purchase them. All these factors contribute to the low productivity of beans in farmers' fields.

Marketing constraints

Farmers grow beans not only for their own domestic consumption, but also as a source of income. Many farmers value beans as a fast-growing crop, which can be converted easily and regularly to cash, especially during times of need. This role has been assuming greater importance in many countries in the region (Nekesa et al., 1998; E. Asante of World Vision, personal communication), but farmers' attempts to commercialise the crop are faced with numerous problems:

- limited market knowledge
- low prices
- production located far from main markets
- poor infrastructure in rural areas, resulting in expensive and often unreliable transport

- limited land and insufficient labour, resulting in the production of small quantities that cannot offset marketing costs
- limited access to market information, resulting in reliance on exploitative middlemen (Since beans are not processed into alternative valued-added products, farmers are unable to offer a range of products to exploit market niches.)
- inappropriate storage facilities and inability to control post-harvest diseases and pests (especially bruchids), meaning that farmers are forced to sell much of their produce at harvest when prices are low due to excess supply
- lack of alternative sources of income in some areas, such as Kisoro in southwestern Uganda, resulting in high dependency on beans as a cash crop (Farmers are unable to hold their produce until prices improve.)

Problems facing national agricultural research systems

Breeders, in collaboration with other scientists, are expected to provide solutions to farmers' problems. This basically involves developing well-adapted bean cultivars with high yield potential, desirable seed characteristics, tolerance to the major biotic and abiotic constraints, and acceptability to consumers. However, in carrying out their responsibilities, bean breeders in the national agricultural research systems (NARS) in the region are faced with several problems that slow down the realisation of their goals. These problems and their associated constraints (which include local varieties that lack adequate resistance to low soil fertility, pests and diseases) are attributed to the following:

- lack of reliable sources of genetic resistance for some problems, such as angular leaf spot, anthracnose, and low soil N and P
- lack of knowledge about the epidemiology of major diseases
- available materials are mainly of Andean origin and have a narrow genetic base with limited opportunities for further improvement
- few well-developed hybridisation programmes because of lack of experienced and skilled breeders
- inadequate financial resources to develop effective breeding programmes

National agricultural research and extension systems (NARES) are faced with four main problems:

- They are under pressure to demonstrate impacts from bean research.
- Most of the technologies developed using the typical Western-style on-station research has failed to produce any impact on smallholder farms in Africa because farmers were not adequately involved in the development of these technologies. Consequently, NARES are under pressure to involve all stakeholders in the development and transfer of technologies.
- The information exchange system between and within countries is poor.
- Inappropriate research and extension methods are often used.

In addition, the needs of farmers, traders, and consumers are not well known. This is due to the wide diversity of needs for different users, locations, and market sectors, which makes it difficult to provide single, focused solutions.

Problems of seed producers

Many public and private commercial companies have included the bean in their seed production enterprises in the last two decades. However, seed producers like Kenya Seed Company have reduced their scale of operation because they have found the bean seed business unattractive due to unstable demand, small and localised markets with a wide range of buyer profiles, and the high cost of producing good-quality seed. In Rwanda, the foundation seed project Appui au Secteur Semencier du Rwanda (ASSR, which has replaced Service de Semences Selectionnees, SSS) sold bean seed at Frw 240 to farmers and NGOs while the actual cost of production is Frw 269.80 (Kimani, 2000). If the cost of providing technical services (technicians and breeder visits to production fields) is included, the true cost was Frw 420.23. Thus, seed production was only possible because of price support by the Rwandan government and the Belgian Co-operation and Development Agency (BADC).

Farmer-producers of bean seed are constrained by a lack of information on the markets and such things as the types of seed required, quantities of each, prices and their fluctuations, and locations of markets. They are poorly linked with research and the commercial seed sector, and they do not have access to basic seed of new varieties. In addition, they lack the resources and knowledge for producing, cleaning, packaging, labelling, and marketing quality seed. Because of limited resources of land and capital, farmer seed producers can only produce limited quantities. Moreover, the informal seed sector is not officially recognised, either nationally or internationally. This further restricts access to lucrative markets for certified seed.

Land scarcity

Land is a major resource for bean-growing families, but because of rapid population growth, the availability of productive land has declined. This has resulted in intensification of cropping and a subsequent decline in soil fertility in previously high-potential bean-producing regions (e.g., Western and central parts of Kenya and several regions in Rwanda and Burundi). Land parcels per family tend to be small in high-potential and urban areas and are larger in areas of moderate and low potential, partly due to deliberate government policies on land adjudication and the natural ability to sustain livelihoods. Typically, high-potential areas also have high population densities. Wortmann et al. (1998a) noted that there is a strong correlation between population density and intensity of bean production.

Major constraints to increasing productivity by land-scarce families include the following:

- Local varieties are not well adapted to low soil fertility, drought, and associated soil-borne diseases such as root rot and charcoal rot.
- Land-scarce families either cannot afford to buy fertilisers or these are not profitable to apply when moisture is a limiting factor.
- Continuous cropping results in the build-up of soil pathogens and diseases.
- Because of population pressure, fragmentation of parcels, and concomitant decline in land sizes, there are limited opportunities for crop rotation. This leads to reduced soil fertility and a high incidence of disease.
- Management strategies to control soil fertility, disease, and pests are inadequate.
- Rainfall is irregular or inadequate.
- Low-cost, labour-saving technologies are not available.

STRATEGIES IN SEARCH OF SOLUTIONS

The Pan-African Bean Research Alliance (PABRA), in collaboration with NARES and NGOs, has formulated and implemented several solutions, strategies, and approaches with the aim of alleviating the problems facing the smallholder farming families in the last 15 years. The overall strategy for increasing bean productivity for small-scale farmers has been to develop cultivars with improved yield potential through the introduction, testing, and dissemination of cultivars with genetic tolerance or resistance to the main biotic and abiotic constraints, as well as developing husbandry practices that further alleviate the effects of these constraints. The specific solutions proposed and implemented were to

- develop and make available seed of high-yielding varieties
- develop and make available integrated pest and disease management technologies
- develop and make available soil management systems to improve fertility in rural communities
- develop and make available less labour-intensive technologies for soil management

ACHIEVEMENTS

Improved cultivars

Between 1992 and 1996, 69 bush or climbing bean cultivars were released and disseminated by bean researchers in eight EASTERN Africa countries (David, 1997; David et al., 2000). Several others were in advanced evaluations. The released varieties showed improved performance in on-station and on-farm trials and were superior to local landraces in grain yield or resistance to diseases, pests, or had another important trait

(Gridley, personal communication). Yield advantage varied with countries and test environments. For example, yield improvement of new bush bean cultivars over the check (often a previously released cultivar) was 5% to 69% in Ethiopia; 14% to 33% in Kenya; 5% to 33% in Rwanda; 8% to 18% in Tanzania, 51% in DR Congo, and 22% in Uganda. The maximum increases for climbers ranged from 15% to 30% in Rwanda and 2% to 35% in Tanzania. In western Kenya, the introduction of root-rot-tolerant climbing beans and bush beans increased bean yields in farmers' fields from less than 0.2 t/ha to over 0.8 t/ha per season (Nekesa et al., 1998). K132 out-yielded the local improved cultivar, K20, by 38%, and a popular landrace, 'Kanyebwa', by 35% in farmers' fields in Mbale under intercropped conditions (David et al., 2000). Another new release, K131, out-yielded K20 by 79% and 'Kanyebwa' by 69% in the same trials. These and other reports clearly indicate that varieties with significant yield increases have been developed and released by the project and its partners. It is significant that improved yields have been realised in the fields of small-scale farming families. Increased yields should translate into more income and improved food security and should, therefore, contribute to poverty alleviation in rural areas. The negative aspect of increased yields is a decline in prices as a result of improved supply. Training farmers in marketing and management of small businesses may become necessary as production rises and local markets cannot absorb additional supplies. Release of several varieties to farmers also no doubt contributed to the conservation of biodiversity on the farm. Genetically diverse varieties contribute to stability in production and reduce the chances of widespread disease epidemics.

Nurseries with reliable resistance to diseases and pests

The project has released many nurseries to the national programmes in the last 15 years. These either originated from CIAT-Colombia or were reconstituted as a result of further testing by project scientists in Africa in collaboration with NARS scientists. From 1985 to 1996, 349 breeding nurseries—international bean nurseries (IBN) and international bean yield adaptation nurseries (IBYAN)—150 constraint nurseries, and over 3000 segregating populations and advanced lines were distributed to NARS in Africa (Strachan et al., 1999). Another 300 segregating multiple-constraint populations with specific combinations of resistance for Africa were distributed in 1997, 1998, and 1999 (H. Gridley, personal communication). These included populations with combinations of resistance to angular leaf spot, anthracnose, bean common mosaic virus, and common bacterial blight and tolerance to low soil fertility. Nurseries with resistance/tolerance to bruchids and bean stem maggot were distributed to a few NARS for further evaluation (K. Ampofo, personal communication). Lines with tolerance to low soil nitrogen and to P- and acidity-related problems and resistance to root rot and angular leaf spot were sent to the multiple-constraint breeding programme based at the University of Nairobi (C. Wortmann and R. A. Buruchara, personal communication). Most of these lines are being used as parents in the hybridisation programme.

These nurseries offer unique opportunities for improving resistance to major biotic and abiotic constraints by NARS breeders and increase the available genetic diversity for beans on-station, and eventually on-farm. This has long-term implications for the stability of bean production in Africa. The negative impact of these materials is the introduction of the I-gene, which causes a hypersensitive necrotic reaction (black root) when the bean plant is attacked by certain virus strains. This gene was not found in the large-seeded materials widely grown in Africa (Andean gene pool) but is common in small-seeded beans in Latin America. Additional effort is required to incorporate the bc-3 gene to protect large-seeded materials with the I-gene (Mukoko et al., 1995). Nurseries with resistance to the major diseases were constituted and distributed to NARS through the project—and in some cases, by a NARS/Network sub-project. Nurseries include rust, anthracnose, root rot, bean stem maggot, angular leaf spot, bean common mosaic virus, common bacterial blight and PRELAAC, as well as a multiple constraint nursery and the Pan African disease nursery. Others, such as a charcoal rot nursery, are being constituted.

Varieties resistant to diseases and pests

Varieties with resistance to one or more diseases have been released by one or more NARS. For example, Awash 1 with resistance to rust was released in Ethiopia in 1989; Raozin' Alaotora, released in Madagascar in 1995, is resistant to rust, ascocytia, and angular leaf spot; CAL 143, released in Malawi, is tolerant to angular leaf spot; Vunikingi, a climber resistant to *Fusarium* root rot, was released in Rwanda in 1985; Uyole 98, released in Tanzania, is resistant to anthracnose; while K131, released in Uganda and Zambia, is resistant to bean common mosaic virus and bean common mosaic necrosis virus.

Fast-cooking varieties

Traditionally, the dry bean is regarded as a slow-cooking food. In central Kenya, a cooking time of three hours is regarded as normal for unsoaked dry beans. Several reports show that one reason for the rapid adoption of some of the varieties released by the project is that they cook faster than traditional varieties and therefore save

on cooking time and fuel costs (and save forests). For example, among the factors leading to the rapid adoption of Lyamungu 85 in Hai, Moshi Rural, and Mbulu Districts in Northern Tanzania was fast cooking (10% faster than Canadian Wonder) and palatability (Kweka et al., 1998; Nkonya et al., 1998). Muthamia (personal communication) also attributed the rapid adoption of climbing bean varieties in the central highlands of Kenya partly to fast cooking. Research results show that pre-soaked seed of A262 (released in Ethiopia) cooks in 20.7 minutes, compared to 24.2 minutes for commercial local check (Kirkby, unpublished data from 1999). In the same trials, pre-soaked seeds of Roba-1 (also a new release in Ethiopia) cooked in 16 minutes, compared to 22.9 minutes for the commercial check. In Uganda, new releases CAL 96, MCM 5001, and white Haricot cooked in 103, 96, and 56 minutes, respectively, compared to 105 for the popular local check, K20. Shellie-Dessert and Hosfield (1990) reported that in trials conducted among 15 households in southern Rwanda, Calima required 16% less firewood and 8% less time to cook than the slower-cooking cultivar, Rubona 5, and a haybasket cooker used 40% less firewood than the traditional fire cooking method.

The faster-cooking varieties have major implications for the rural and urban poor, gender equity, and conservation of biodiversity. The direct effects are savings in cooking time and fuel costs, mainly for women, who are responsible for cooking. Adoption of fast-cooking varieties reduces the quantities of firewood used and the time spent in search of it. For urban consumers, money will be saved on expensive fuels (kerosene, charcoal, electricity, and natural gas). Fast-cooking foods are particularly appreciated by the urban poor because of the costs involved. Indeed, the popularity of maize meal (*ugali*, *nshima*) in many urban and rural areas is that it cooks in less than 20 minutes. Faster-cooking varieties will contribute to reducing the pressure on forests: encroachment on forests in search of firewood and charcoal is a major problem in the region. In this sense, adoption of fast-cooking varieties is likely to be environmentally friendly and contribute to the conservation of biodiversity.

Tolerance to abiotic stresses

One of the strategies developed to deal with the problems of declining soil fertility was to screen germplasm for tolerance to soil low nitrogen, phosphorus acidity (and associated manganese and aluminium toxicity), and efficient utilisation of soil nutrients. This process involved primary screening at three locations separately for N, P, and soil acidity, followed by multi-site secondary screening with yield as the main selection criterion. By 2001, the process was in the fourth cycle (BILFA IV). Several lines resistant to one or more abiotic constraints and with reasonable yield potential were identified and tested in farmers' fields in several countries. Some of these were adopted.

Two examples will illustrate the progress made in this area. Bean yields in western Kenya had declined to critical levels by 1992/93, and 70% of farmers had stopped growing bush beans altogether in the long rains of 1994 (Salasya and Otsyula, 1998). Some farmers attributed this to some 'black rain' which occurred in 1990, or witchcraft (Nekesa et al., 1998). Others believed the soil had become 'tired'. On the basis of their experiments, researchers found the cause of the problem was a very high incidence of root rot, a decline in soil fertility, and a BSM infestation—three factors that they found to be related. By introducing root-rot-resistant bush and climbing beans, fertilisers, green manure (such as mucuna and tephrosia), bean yields in farmers' fields rose from 0.2 to 0.8 t/ha. In 1996, 100% of the seed recipients were growing at least three varieties.

In Gikongoro Prefecture of Rwanda in 1993/94, beans could hardly grow due to high soil acidity (pH 4), an associated deficiency of phosphorus and nitrogen, and a high incidence of root rot. Raising the pH to 6.7 required about 60 t of lime, which was simply out of reach for farmers. The World Vision team, in collaboration with CIAT and ISAR, developed a technique of localised application of lime in planting holes only (E. Asante, personal communication). This adjustment of pH, coupled with resistant varieties, raised average yields from 0.4 to 2.9 t/ha. With the introduction of improved root-rot-resistant climbing bean varieties, yields of 3.5 t/ha have become common. Adoption rates of nearly 100% in Gikongoro (E. Asante, personal communication) and 48% in other areas (Sperling and Loevinsohn, 1993) have been reported.

IPM strategies in use against pests of common bean

Studies on integrated pest management (IPM) against the BSM (the most important bean pest) and bean root rot (BRR) have been conducted using farmer participatory approaches in Embu and Kakamega in Kenya; Kisoro in southwest Uganda; Areka in Ethiopia; and Gikongoro in Rwanda (CIAT, 1992; Ndiritu et al., 1997; Otsyula et al., 1998). The main components evaluated were resistant or tolerant varieties, cultural methods, organic amendments (such as green manure, farmyard manure, and ridging), inorganic fertilisers, fungicides, and insecticides. Results showed that the incidence and severity of BRR, BSM, and low soil fertility (mainly low availability of soil P and N and soil acidity) were related. In general, BRR and BSM

were most severe under low soil fertility. Although application of individual components could increase bean yield, an integrated approach was more effective. Of the green manures and mulches tested (*Calliandra*, *Sesbania*, mucuna, tephrosia, *Dolichos lablab*, grass, coffee pulp, wattle bark, tithonia, soybeans, and buckwheat), mucuna, tephrosia, lablab, and tithonia were the most promising. Among fertilisers and manures, diammonium phosphate and farmyard manure gave the best results. Benlate reduced the incidence of root rot by 50% to 70%. A combination of improved soil fertility and resistant varieties was the best option for controlling BRR and BSM.

Over 300 farmers, who were trained through a collaborative effort of ABLH, KARI, AHI, extension officers, and the CIAT team, further tested various packages. Results showed that farmers preferred a combination of two components: varieties and manure, an option farmers had previous experience with. Further dissemination of IPM technologies by training farmers to train other farmers culminated with the training of 450 farmers over a two-year period. All farmers were provided with seeds at the end of training. Evaluations showed that 420 farmers had adopted the technologies, especially the root-rot-resistant climbing variety. The high adoption rate was attributed to the varieties' tolerance to one of the major production constraints, potential gain in income, a good return to investment, and compatibility of the technology with the existing farming system.

Similar approaches were tested in Gikongoro (E. Asante, personal communication); however, in this Rwandan prefecture, tephrosia was found to be the only green manure to survive in the acid soils. Its main drawback is low biomass yield. Composted night soil gave excellent performance on beans, maize, and potatoes but was discontinued because of potential health hazards. Although these technologies were labour intensive, adoption was high (estimated at 100%). The involvement of farmers in these trials increased their awareness of soil fertility options and innovative approaches. Tephrosia leaves also gave consistently good control of bean bruchids in on-farm trials conducted in Iganga District, Uganda, but adoption was not significant (Wortmann et al., 1998b).

Regional networks established

Development of regional networks was another crucial step in institutionalising and promoting participatory approaches in bean improvement and also in ensuring that research benefits were shared across national boundaries. Two networks were created in the mid-1980s soon after the arrival of CIAT scientists in the region. These were the East African Bean Research Network (EABRN), comprising the national programmes of Uganda, Kenya, Tanzania, Ethiopia, Sudan, Madagascar, and Mauritius, and RESAPAC, which catered for Rwanda, Burundi, and DR Congo. In 1995, RESAPAC and EABRN were replaced by the East and Central Africa Bean Research Network (ECABREN), with responsibility for nine countries (DR Congo, Uganda, Rwanda, Burundi, Kenya, Northern Tanzania, Sudan, Madagascar, and Ethiopia). At the same time, the Southern Africa Bean Research Network, comprising the national programmes of Malawi, southern Tanzania, Zambia, Zimbabwe, Angola, Mozambique, South Africa, Botswana, Swaziland, Lesotho, and Angola, was formed. These networks provided a forum for the exchange of information, materials, and technologies. Technologies developed in one country could be used in another with similar conditions. For example, although production technology for climbing beans was originally developed in Rwanda, it spread rapidly to Kenya, Uganda, Congo, Ethiopia, Malawi, and Tanzania, facilitated by exchanges of visits, meetings, publications, and germplasm. Regional working groups were created with representation from all member countries. Breeding and constraint nurseries were constituted and made available to all countries. Variety releases increased considerably.

Climbing beans introduced

The six climbing bean varieties (Vunikingi, Umubano, Gisenyi, Flora, Gisenyi, and Ngwinurare), originally introduced in Rwanda in the late 1980s, have spread across countries in the region in the last six years and have become household names among farmers. Climbing beans have been promoted by the project because of their conspicuous yield advantage (about 3 to 1) and their maximum use of limited space (both horizontally and vertically) in a manner comparable to high-rise commercial and residential buildings in urban centres. Realising their potential in meeting food and income needs, farmers have made further investments to exploit this potential. For example, staking materials have been cited as a major constraint to adoption. However in western Kenya and Rwanda, farmers have experimented and used alternative staking material such as stalks of nappier grass and cassava and sorghum stems. Some have started planting nappier grass and fast-growing trees such as eucalyptus and tithonia for this purpose. Others have bought staking materials from forests and neighbours (Nekesa et al., 1998).

Participatory breeding methods developed

The pioneering work on participatory selection of improved bean varieties in Rwanda showed that faster identification of superior varieties and rapid adoption could be achieved through this approach (Sperling and Berkowitz, 1994). Results showed that selections produced up to 38% more than local mixtures. Twenty-one more varieties suited to a wide range of growing niches were identified over a period of nine years. Adoption rates of 40% for improved climbing beans were reported after eight years. Since then, the participatory approach has been embraced in other project activities. Participatory programmes are in place in Ethiopia, Tanzania, Malawi, and Rwanda. Farmer participatory approaches are also being used in programmes to improve soil fertility (Farley, 1999).

Dissemination and adoption of improved cultivars

To ensure that the benefits of research reach as many intended beneficiaries as possible, mechanisms were developed to disseminate new, well-tested technologies to farmers in many countries. This basically involved development of innovative seed delivery systems to complement and strengthen existing seed distribution channels and, in other cases, to initiate new ones.

Varieties in markets

Farmers, farmer seed producers, NGOs, and quasi-governmental and private seed companies in several countries, are producing seeds of bean varieties released in the last decade. In Rwanda, ASSR, in collaboration with ISAR and other NGOs, has had a steady record of producing, cleaning, and packaging seeds of many improved varieties for several crops in the last 10 years. Bean seed production was 26,304 kg in 1990/92, 13,786 kg in 1995, 35,076 kg in 1996, 90,678 kg in 1997, 61,514 kg in 1998, 114,230 kg in 1999, and about 50 t in 2001. Seed was produced for bush cultivars (Urugezi, RWR 719, RWR 1802, RWR 911, RWK 10, A321, SCAM 80/15, and RWR 13121) and also for climbers, such as Vunikingi, Ngwinurare, I-27, I-30, E25, and Essai. In Kenya, certified seeds of pre-PABRA varieties (the GLP series) are regularly produced by the Kenya Seed Company and East African Seed Company and are available in shops in many parts of the country. Similar seed organisations are found in Uganda (Uganda Seed Project), Tanzania, and Ethiopia. However, the number of bean varieties produced by each company is normally less than five. Less well-established varieties are produced and distributed by farmer seed producers, national bean research programmes, and NGOs. For example, the Bean Improvement Programme (BIP) in Malawi released six varieties in 1995 (Phiri et al., 1998). These were CAL 143 (Napilira), CAL 113 (Muluwa), A197 (Nagaga), DRK 57 (Sapatsika), A344 (Mkhalira), and A286 (Kambidzi), all CIAT materials. Seed of these varieties was multiplied by farmers contracted by the project and then distributed in small packets through merchants, schools, agricultural research stations, extension agents, and NGOs in 1996 through 2001.

Adoption

There is considerable evidence of adoption of varieties released and disseminated by the project and its partners in the last 10 years (David, 1997; Kweka et al., 1999; Phiri et al., 1998; Salasya and Otsyula, 1998; Sperling and Berkowitz, 1994; David, 1997; Hoogendijk and David, 1997; Nekasa et al., 1998; Nkonya et al., 1998; David et al., 2000). In Kenya, Salasya and Otsyula (1998) reported adoption of at least three varieties by 100% of farmers who received the seed of six climbing varieties introduced through the network in Kakamega and Vihiga Districts. Muthamia (personal communication) estimated nearly 100% adoption of the same climbing varieties by farmers in central Kenya. In Tanzania, Kweka et al. (unpublished) reported 87% adoption of Lyamungu 85 in Hai, 91% in Moshi, and 73% in Mbulu in a survey conducted in 1996 and 1997. In Bukoba District in Tanzania, David (1997) reported 11% adoption of Lyamungu 90 in a survey conducted in 1998. Mekbib (2002) reported 45% adoption of Mexican 142 and 13% for Awash 1 in eastern Ethiopia. In Uganda, David et al. (2000) found adoption rates of 98% for K132 and 47% for K132 in Nabongo Parish, Mbale District four years after initial seed distribution. In Rwanda, Sperling et al. (cited by David, 1997) found adoption rates of 71% and 72% for the improved variety Umubano among traditional and new growers of climbing beans. The study was conducted six seasons after seed dissemination by Project Kigali-Nord.

A large study conducted nationwide in 1992/93 revealed that 41% to 43% of households in Rwanda were growing improved climbing beans introduced five years earlier (Sperling and Berkowitz, 1994). Use of climbing beans had increased to 48% one year after the genocide, primarily due to the activities of the Seeds of Hope Project and NGOs (Sperling and Scheidegger, 1996). Adoption and impact studies in Burundi and DR Congo are few, probably due to the continued insecurity; however, an adoption rate of 20% was reported in the early 1990s for Kaki, released in 1987 (David, 1997). Although limited information is available in

SABRN countries, seed sales by the Malawi Bean Improvement Project indicate rapid dissemination of new varieties to farmers (Phiri et al., 1998; R. Chirwa, personal communication). Quantities of seed of new cultivars sold were 1,088 kg, 11,009 kg, and 3,451 kg in 1996/97, 1997/98, and 1998/99, respectively. The seed was sold in 100 g, 250 g, and 500 g packets. Impact studies are yet to be conducted.

Decline in market prices

The expected decline in market prices in response to the increased supply of beans has been observed in many countries. For example, prices had fallen to Frw 80 per kg in Kigali in January 2000 because of an increased supply of beans harvested in December (A. Musoni, personal communication). Prices on the week ending 16 January 2000 ranged from Frw 45 to Frw 110 per kg with most markets in the range of Frw 45 to Frw 60. The lowest prices were in Ruhengeri, a major area for climbing bean production due to its good rainfall and fertile soils, resulting in high yields. Conversely, prices were highest in Nyagatare, a semi-arid area in the northeast of the country. At planting, 1 kg of beans was selling for up to Frw 200. In western Kenya, bean prices rose to Kshs 80 to Kshs 100 in 1993/94 due to low production as a result of serious root rot, BSM, and a decline in soil fertility, which forced many farmers to stop growing beans. Only the rich could afford beans (Nekesa et al., 1998), and consumption of beans soon became a status symbol. However, production rose as many farmers adopted root-rot-resistant varieties and prices stabilised at Kshs 30 to Kshs 40. Women's groups in Mbale (Uganda), who have adopted the new varieties, complained of low bean prices in local markets during a field visit by the authors in January 2000. The implication of increased production is affordability of beans to the large group of rural and urban poor, who rely on beans to meet protein requirements. For producers, searching for alternative markets and better storage facilities may be the way to cope with increasing production.

RETURNS TO INVESTMENT

Gross returns

Wortmann and Johnson (1999) estimated that the cumulative net value of CIAT- assisted bean varieties in five countries (Tanzania, Uganda, Kenya, Ethiopia, and Rwanda) up to 1998 was US\$171,218,925. This works out to about \$11.4 million per year for 15 years and about \$182.6 million at the end of 1999. CIAT headquarters placed three PABRA bean research activities among the top five with the highest internal rate of return and the present value of expected net benefits of the Centre's 40 activities (Strachan et al., 1999). Climbing beans in Africa were assigned the highest rate of return of all activities (97.6%), followed by bean disease research in Africa (79.3% and \$103 million) and Mesoamerican genepool in Africa (77.4% and \$49.7 million) in third and fourth place, respectively. These data clearly indicate that the net benefit from new bean varieties is worth many times more than the entire project budget for the same period and therefore has a high cost-benefit ratio.

Benefits to women and resource-poor farmers

Women and resource-poor farmers have benefited from bean research through

- improved incomes as a result of increased production from the introduction of high-yielding cultivars with resistance or tolerance to major biotic and abiotic constraints
- improved food security (David et al., 2000; Sperling and Berkowitz, 1994)
- reduced demand for fuel wood and time spent collecting firewood (Nkonya et al., 1998) and foraging for wild vegetables

David et al. (2000) showed that higher incomes from adoption of K131 and K132 in eastern Uganda bettered women's lives by improving household welfare and increasing both household and personal income. The negative impact of adopting improved varieties included more labour for weeding an expanded area and for harvesting and sorting increased produce, along with marital conflicts, as reported by some households.

Evidence of increased income

Increased production due to improved yields of the new bean varieties is expected to increase food availability in households and create a surplus for sale. It is therefore reasonable to assume that improved production, reported by many farmers in surveys conducted in several countries and in national statistics, must have contributed to increased household incomes. A few examples illustrate this. In Mbale, Uganda, 88% of the adopters of K132 reported income gains due to higher productivity and price (David et al., 2000).

K132 was quickly accepted by traders and, by 1997, had captured a significant share of the market for Calima types, commanding a premium price of Ush 150 to Ush 500 in 1988, Ush 50 to Ush 100 above the price of K20. On average, in the first season of 1998, adopters sold 92 kg of K132 at farm gate value of Ush 26,169, compared with 48 kg for all other bean varieties combined. Farm families used income gains from K132 for both short-term consumption and productive investments, including household items such as soap, paraffin, candles, sugar, and salt (88%); food (69%); medical expenses (68 %); clothes (66%); personal items, such as bicycles and radios (39%); school fees (28%); to purchase new livestock (23%); renting land (18%); and paying taxes (18%).

In northern Tanzania, switching from Canadian Wonder (the most widely grown local variety) to Lyamungu 85 was estimated to increase bean production by about 473 tons, equivalent to 1.6% to 1.9% of total bean production (Nkonya et al., 1998). This area is a major exporter of beans to Kenya and it is reasonable to assume part of the increased yield was marketed, generating additional income for farmers. Although the economic impact of improved varieties in western Kenya is not known, farmer-to-farmer sales and sales to local markets have increased with improved production of root-rot-resistant bush and climbing bean varieties.

Cost-effective research through networking

There is a lot of interdependence among national agricultural research institutes (NARIs) within each network and between the two networks, which has contributed to savings in time and resources and improved outputs. A few examples will illustrate this. Each year a few NARS are given the responsibility of evaluating a disease nursery, such as anthracnose, rust, or root rot, to identify resistant lines. Both the information generated and the lines are shared by other NARS through working groups or workshop proceedings and germplasm exchange. This has been the characteristic division of labour among NARS in each network for the last 15 years. For example, the Malawian National Programme learnt methodologies for BSM management from Selian Agricultural Institute in Tanzania and obtained a BSM nursery from the Tanzania national programme, BILFA nurseries from several countries, BCMV from the Zimbabwe national programme, and BILFA screening methodologies from CIAT-Uganda (R. Chirwa, personal communication), and they depend on the South African programme for confirmation of resistance to ALS. In turn, other NARS in SABRN depend on the Malawian programme for SARBEN and SARBYT and multiple constraint nurseries. The same situation obtains for almost any other NARI in ECABREN.

POTENTIAL AND FUTURE PROSPECTS

Despite the tremendous progress made by PABRA, NARS, and other partners in bean improvement, a lot more remains to be done to consolidate and further improve the prospects of meeting the growing demand for beans in Africa.

Yield improvement

Opportunities to increase grain yields within race Nueva Granada, which is widely grown in Africa, are limited because of the low genetic variation for this trait. It will be necessary to introduce yield genes from germplasm of the Mesoamerican gene pool, which normally shows higher yield potential. Most NARS in the region have used intra-racial crosses, mainly of the Andean gene pool, because of the difficulties experienced with interracial crosses. These include F₁ hybrid dwarfism, lack of adaptation of introduced germplasm, virus-like symptoms in segregating generations, low probability of recovering desirable recombinants from populations of manageable size, and the rather conservative breeding methods adopted by breeders. It will be useful to include inter-racial and probably intergeneric crosses in future breeding programmes. These can be facilitated by bridging parents such as ICA Pijao, which cross easily with genotypes from Andean and Mesoamerican gene pools. The potential of high-yielding climbing beans in the improvement of bush beans has not been investigated in the region.

Multiple-constraint breeding

An alternative to yield improvements *per se* is incorporating resistance to yield-reducing traits. Losses due to these factors are well documented (Wortmann et al., 1998a). Future breeding strategies should focus on reducing these losses by introducing as many resistance genes in popular cultivars as possible. In many cases, several production constraints are limiting, and incorporating resistance to one will not result in significant changes. Resistance to several constraints is particularly essential for smallholder, resource-poor farmers who have a limited ability to improve the production environment. However, the choice of priority

constraints will depend on differences in the severity of constraints in a producing region. Breeding efforts should be concentrated on the most limiting constraints to productivity. Multiple-constraint breeding should be an integral part of all regional breeding programmes.

Climbing beans

Climbing beans offer considerable opportunities for increasing productivity for smallholder farmers because of their high yield potential. However, they occupy a relatively small area in the region at present. Some cultivars, such as Umubano, have broken down with *Fusarium* wilt. Others lack the preferred seed characteristics (such as red mottled, which is traded in local, domestic, and regional markets). Most are adapted to high altitudes with high rainfall. There is a need to develop new types that are adapted to medium- and low-altitude areas characterised by high temperatures, moisture stress, and often, low soil fertility. Climbing beans offer a unique opportunity for intensifying production for land-scarce farming families in rural and urban areas.

Marker-assisted selection

Most programmes in the region rely on conservative breeding approaches, which may be less efficient in identifying genotypes with desired traits. This is often further complicated by environmental influences and genotype-by-environment interactions that further reduce the efficiency of recovering desirable genotypes from segregating populations. The use of marker-assisted selection for both qualitative and quantitative characters (quantitative trait loci, or *QTL*) may improve the recovery of desirable traits with higher precision. Markers for important traits, such as resistance to anthracnose, rust, and common bacterial blight, have been developed. Markers for angular leaf spot and root rot are being developed in collaboration with CIAT breeders in Colombia. Training breeders in the use of markers is essential for this tool to have an impact on improving the efficiency of their programmes.

Snap beans

Breeding snap beans has received relatively less attention in the region despite their importance as a source of income for thousands of smallholder farmers. Their productivity is severely limited by susceptibility to rust and angular leaf spot. Smallholder farmers are also likely to be adversely affected by stringent new regulations for acceptable residue levels and use of chemicals against pests and diseases by importing countries, particularly the European Union. The new regulations seem to favour natural methods of disease and pest management. Resistance to major diseases and pests is therefore likely to be more important in snap bean production for export markets. Consumer preferences and quality traits are particularly important for export markets. Many countries have expressed an interest in introducing improved snap bean cultivars to their farmers. Locally developed cultivars will be more accessible to smallholders who are not allowed to produce seed of cultivars patented by private breeders and companies. These companies have set the minimum amount of seed that can be bought, which is often beyond the means of smallholders. For example, the minimum package of snap runner bean in Kenya is 25 kg, which costs about Ksh 25,000 (US \$350).

Runner beans

Runner beans are traditionally grown at elevations above 1800 masl in East and Central Africa. In Kenya, runner beans are a major legume in high-altitude regions because they are more tolerant to low temperatures and high rainfall than the common bean. The runner bean is more resistant to common bean diseases, and because it crosses easily with common bean, it has been proposed as a source of resistance. Dry runner bean (also known as butter bean) is a climber produced mainly for local consumption and sale in domestic markets, while the snap type is a high-value export crop. The main constraint to production by smallholder farmers is photoperiod sensitivity. Most snap cultivars grown in the region are long-day and require extended light for optimal productivity. Crossing between local short-day and introduced long-day cultivars will create populations from which short-day snap types can be selected. The selected lines will improve productivity in high-elevation regions, increase genetic diversity, stabilise production, improve production choices, and provide an additional source of income for smallholder farmers.

Canning quality

One of the most important value-added bean products are canned beans, which are sold in local, domestic, and international markets. Local processing industries provide regular market outlets for smallholder farmers. However, production has not met the demand, mainly because of stringent quality requirements and

reliance on disease-susceptible cultivars. Production in the region is largely based on Mexican 142, which was released for commercial production in the early 1950s because of its high canning quality. It is highly susceptible to rust and anthracnose and is low yielding. Except for Ethiopia, most national programmes have not made an effort to develop improved canning beans. There appears to be a growing interest in canning beans (white and dark red kidneys) in the processing industry. New bean-based products have been produced and found in shops and supermarkets in major towns in the region. This offers new opportunities for involving smallholder farmers in the product chain and should be exploited.

Nutritional quality

Micronutrient deficiency in local diets is a widespread problem in Africa. The most deficient nutrients include vitamin A, iron, and zinc. Iron deficiency causes anaemia and has prevalence rates of over 60% in sub-Saharan Africa. It is most severe among children and pregnant and lactating mothers. Zinc deficiency affects cognitive and intellectual development. Although food fortification and supplementation are being implemented as strategies to reduce this problem, they are limited in coverage because of the heavy costs involved and are not sustainable. Natural fortification through plant breeding is a cheaper, probably more effective and sustainable approach. Recent studies have shown that there is considerable variation in iron and zinc concentrations in the common bean (Beebe et al., 2000; Kimani and Karuri, 2001). Selection for micronutrient-dense bean cultivars is therefore possible. QTLs for iron and zinc concentrations have been identified (Beebe and Blair, 2001) and can be transferred to locally popular cultivars. Local landraces, commercial cultivars, and breeding populations should be screened for these traits and micronutrient-dense cultivars disseminated to bean growers.

Drought tolerance

Limited studies on drought tolerance in beans have been conducted in the region. Drought occurs frequently in the region, causing severe yield losses. Yield losses due to moisture stress, which may occur early, mid, or late in the season, have been documented (Wortmann et al., 1998a). Although breeding for drought tolerance *per se* is complicated (White and Singh, 1991), alternative strategies should be sought. For example, earliness is a mechanism for avoiding drought, which may be useful in drought-prone areas with short growing seasons. Unfortunately, little work has been done to develop early-maturing bean cultivars in Africa.

Breeding for intercrop systems

Over 95% of the beans produced by smallholder farmers is grown in association with cereals, root crops, other legumes, and bananas. However, most breeding work is done in sole stands. It is not clear whether selection in intercropped conditions could improve productivity or even whether different types of beans would be selected. The limited information available on selection in different cropping systems is contradictory: some studies indicate no influence and others advocate selection in cropping systems in which production is intended. However, none of these studies has been conducted in bean-growing regions in Africa. Information on these aspects would be a useful guide for breeding programmes in Africa.

Introduction of new seed types

Preferences for seed types for local consumption or sale in local markets in Africa are well documented (Voysest and Dessert, 1991; Munene and Grisley, 1992; Wortmann et al., 1998a; Kimani et al., 2000). Breeding programmes are therefore designed to respond to these needs. How rigid these preferences are is not known, although recent information in western Kenya indicates that farmers are willing to grow non-traditional seed types and are ready to make trade-offs. In this region, farmers who have traditionally grown large-seeded red-mottled, pinto, or dark-red kidneys (which are not grown because of root rot) are now producing small blacks, medium pinks, and medium red-mottled that are resistant to root rot. Results of screening germplasm for tolerance to biotic and abiotic stresses indicate that some of the most resistant and high-yielding genotypes do not conform to preferred seed types. Consequently, these were not disseminated to farmers. It would be interesting to conduct studies on farmer reactions and acceptance of these non-traditional seed types, which include cariocas, small blacks, popping beans, brown, and other types.

CONCLUSION

Considerable progress in developing bean cultivars responsive to the needs of smallholder farmers has been made by the Pan African Bean Research Alliance with its NARS partners and other stakeholders. Problems

facing the various actors have been documented and solutions sought. High-yielding cultivars have been developed and their seed disseminated through innovative ways designed to reach those farmers who are not catered for by formal systems. Breeding programmes have been initiated and/or strengthened by an improved flow of germplasm and back-up activities by CIAT scientists. Regional networks have been created to coordinate research activities and facilitate the flow of germplasm, literature, and technologies across national boundaries. For the first time, climbing beans with improved yield potential have been introduced and popularised in many countries. Efforts have been made to integrate technological advances in germplasm enhancement, seed delivery systems, disease and pest management, and crop management for the benefit of farmers.

Despite these achievements, many challenges remain. The new cultivars and other technologies should be disseminated widely so that more people can benefit. In many cases, sources of resistance have been identified but in non-preferred seed types. These should be transferred to popular genotypes using recently developed techniques such as gamete selection, marker-assisted selection, and participatory approaches. For other characters where no reliable sources of resistance and other important agronomic characters have been found, it will be useful to screen among the local landraces and accessions available in CIAT's gene bank. Cultivars more appropriate for intercrop systems should be developed. To further ensure that smallholder farmers have not only adequate food for their domestic needs but also growing incomes, cultivars, such as snap and canning beans, that meet market-oriented needs should receive more attention. To ensure quality food and effective management of related health problems, selection for and dissemination of micronutrient-dense beans is imperative.

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BEAN BREEDING FOR AFRICA: STRATEGY AND PLAN

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ABSTRACT

The common bean is the principal grain legume grown by small-scale, resource-poor farmers for food and sale in many countries in sub-Saharan Africa. However, its productivity is severely constrained by many biotic and abiotic constraints, resulting in low production despite rising demand. The International Center for Tropical Agriculture (CIAT), in partnership with national programmes, regional networks, and NGOs, has released several improved bean varieties in the last decade. However, most of these varieties originated from the CIAT breeding programme at its global headquarters in Cali, Colombia. To strengthen the capacity of bean researchers in Africa to respond better to the changing needs of farmers and consumers, the Pan African Bean Research Alliance (PABRA), consisting of CIAT-Africa, the East and Central Africa Bean Research Network (ECABREN), and the Southern Africa Bean Research Network (SABRN), has developed a collaborative strategic plan for breeding high-yielding bean varieties with improved tolerance to major biotic and abiotic stresses, which also meet requirements for domestic, regional, and international markets. Following participatory approaches, breeding programmes for the seven most important market classes have been developed and are being implemented by collaborating NARS, selected on the basis of the importance of a particular market class in their country. Test sites were selected to represent the major bean-growing environments and constraints for each market class. The main priorities for the breeding programmes are (1) yield improvement, (2) identification, characterisation, and utilisation of sources of resistance to major biotic and abiotic constraints, (3) assessment of advanced lines for productivity in intercropped and sole cropping systems, and (4) cooking and nutritional quality.

RÉSUMÉ

Dans de nombreux pays de l'Afrique subsaharienne, le haricot commun est la principale légumineuse à grains cultivée par les petits exploitants pauvres pour l'alimentation et la vente. Sa productivité se trouve toutefois gravement entravée par de nombreuses contraintes biotiques et abiotiques qui ont entraîné une production faible en dépit de la demande croissante. Au cours de la dernière décennie, le Centre international d'agriculture tropicale (CIAT), en partenariat avec des programmes nationaux, des réseaux régionaux et des ONG, a produit plusieurs variétés améliorées de haricot. La plupart de ces variétés provenaient toutefois du programme de sélection du siège de Cali (Colombie) du CIAT. Afin de renforcer la capacité des chercheurs en Afrique travaillant sur le haricot dans le but de mieux répondre à l'évolution des besoins des agriculteurs et des consommateurs, l'Alliance panafricaine pour la recherche sur le haricot (PABRA), comprenant le CIAT-Afrique, le Réseau de recherche sur le haricot en Afrique de l'Est et centrale (ECABREN) et le Southern Africa Bean Research Network (SABRN), a mis au point une stratégie collective destinée à sélectionner des variétés de haricot à haut rendement dotées d'une meilleure tolérance aux principales contraintes biotiques et abiotiques et répondant également aux exigences des marchés régionaux, nationaux et internationaux. Sur la base d'approches participatives, des programmes de sélection ont été élaborés pour les sept principales catégories de marché. Les programmes mis en œuvre par des SNRA travaillant ensemble ont été choisis sur la base de l'importance d'une catégorie particulière à leur pays. Des sites d'essai ont été sélectionnés pour représenter les principaux environnements et contraintes de croissance pour chaque catégorie de marché. Les priorités essentielles pour les programmes de sélection sont (1) l'amélioration du rendement, (2) l'identification, la caractérisation et l'utilisation de sources de résistance aux principales contraintes biotiques et abiotiques, (3) l'évaluation des lignées avancées pour la productivité dans les systèmes de cultures associées ou de monoculture et (4) les qualités culinaires et nutritionnelles.

INTRODUCTION

The common bean is a major staple, providing an important source of protein, minerals, and calorie, for millions of people in rural areas and urban centres in many countries in East, Central, and Southern Africa. The crop is also an important source of income, particularly for resource-poor smallholder farmers and traders who market it not only in local and domestic markets but also in regional and international markets. Beans are primarily grown by women farmers in pure stands or in association with cereals, root crops, and/or bananas in an estimated area of nearly 4 million hectares in Africa. Although the demand for beans has continued to rise in the last two decades due to rapid population growth (over 3%), increasing productivity has been constrained by a wide range of biotic and abiotic stresses and socio-economic factors. These include diseases, pests, declining soil fertility, moisture stress, inadequate supply of quality seeds of cultivars with desirable attributes to meet variable growing conditions and uses, limited access to markets, poor producer prices (especially at harvest), limited storage capacity, and grossly inadequate infrastructure.

Researchers in national agricultural research and extension systems, regional networks, and the International Center for Tropical Agriculture (CIAT), in partnership with farmers, NGOs, and other stakeholders, have made considerable progress in the last 15 years in developing and disseminating technologies designed to address these constraints. Improved bush and climbing bean varieties have been among the technologies with considerable impact in the region. For example, between 1992 and 1996, 69 bush or climbing bean cultivars were released and disseminated by bean researchers in eight countries in Eastern Africa. The improved bean cultivars in the region have been developed through introduction of CIAT germplasm, mainly from Colombia, testing and evaluation of selected lines, and release and dissemination to farmers. Selection from local landraces and hybridisation have also contributed to the pool of released cultivars.

Breeding activities prior to 1985

Before 1985, breeding activities focussed mainly on developing cultivars of dry bush beans and, to a lesser extent, snap beans by national programmes with little collaboration between countries. These programmes followed traditional approaches of introduction, mass selection, and limited hybridisation (notably in Uganda and South Africa), followed by selection by breeders and on-station testing of promising lines in preliminary, intermediate, and national performance trials. Best lines compared to landraces were released formally by national variety release committees, and their seed was multiplied and distributed by publicly owned seed companies or seed projects. In the initial stages, farmers were not involved in the variety selection or testing and were expected to grow the officially released varieties recommended by extension agents. It soon became evident that most farmers failed to adopt the improved varieties and continued to grow their own selections or landraces. In other cases, lines selected from introductions because of excellent resistance to diseases were rejected because of poor seed and plant characteristics. Farmers complained that new varieties were poorly adapted to their growing conditions and did not meet other important requirements, including cooking quality, taste, physical appearance, and compatibility with cropping systems. The supply of seeds for these new varieties was erratic and did not reach farmers in remote regions, if at all, in time for planting. Indeed, the few successful varieties were selections from the landraces, which had retained most of the attributes of their parental populations. The need to involve farmers in the evaluation of new cultivars was realised and researchers included on-farm tests as part of their cultivar-development programmes. However, this feature was incorporated as the last step prior to release of new varieties and, in most cases, was not meticulously followed. It was not a condition for releasing new varieties. The overall result for this period was poor adoption of new cultivars and lack of significant impact, which in turn contributed to frustration among national scientists, extension officers, farmers, and policymakers.

Breeding activities from 1985

Beginning in 1985, CIAT, in collaboration with national programmes, while emphasising the significance of farmer involvement in on-farm trials, started in earnest to experiment with farmer participatory methods in cultivar development. The first programme started at Rubona in collaboration with the Rwandese Institut des Sciences Agronomiques du Rwanda (ISAR). This programme was initiated to compare the performance of cultivars selected by farmers using a system of farmer participatory selection with those selected by breeders under the conventional breeding scheme. Main selection criteria were on-farm yields, long-term varietal use, the maintenance of genetic diversity, and the cost of the screening process. This decentralised selection at the local level was subsequently expanded to DR Congo in the late 1980s and to Tanzania and Ethiopia in 1998. However, the regional breeding programme remained centralised, with national programmes depending on

the supply of germplasm (which included advanced lines, released varieties, and segregating populations) from CIAT. With a regular supply of nearly finished lines, few NARS initiated hybridisation programmes.

Development of regional networks

The development of regional networks was an important step in developing integrated bean breeding programmes and also in ensuring that research benefits were shared across national boundaries. Two networks were created in the mid-1980s soon after the arrival of CIAT scientists in the region: the East African Bean Research Network (EABRN), comprising the national programmes of Uganda, Kenya, Tanzania, Ethiopia, Sudan, Madagascar, and Mauritius; and RESAPAC, which catered for Rwanda, Burundi, and DR Congo. In 1995, RESAPAC and EABRN were replaced by the East and Central Africa Bean Research Network (ECABREN), linking bean improvement activities in nine countries (DR Congo, Uganda, Rwanda, Burundi, Kenya, Northern Tanzania, Sudan, Madagascar, and Ethiopia). At the same time, the Southern Africa Bean Research Network, comprising the national programmes of Malawi, Southern Tanzania, Zambia, Zimbabwe, Angola, Mozambique, South Africa, Botswana, Swaziland, Lesotho, and Angola, was formed. These networks provided a forum for exchanging information, materials and technologies. Technologies developed in one country could be used in another country with similar conditions. For example, although the production technology for climbing beans was originally developed in Rwanda, it spread rapidly to Kenya, Uganda, Congo, Ethiopia, Malawi, and Tanzania, facilitated by an exchange of visits, meetings, publications, and germplasm. Regional working groups were created with representation from all member countries. Breeding and constraint nurseries were constituted and made available to all countries. Variety releases increased considerably. However, most of the germplasm originated from the CIAT bean programme and, later, from the regional programme in Uganda, which served as the distribution hub for the region. However, due to a constant and regular flow of germplasm from CIAT, many national programmes failed to initiate crossing programmes or create new breeding populations.

Decentralisation of breeding programmes

Despite the success in developing and releasing new bean cultivars by the network members, studies in marketing of beans in the region in 1999 revealed a need to develop cultivars that were more responsive to market demands. This was based on the observation that although most smallholders grew beans for their domestic consumption, sizeable quantities were traded in domestic, regional, and international markets. It was evident that increased production was driven not only by the need to meet food needs for households, but also to generate income from sales in their localities (neighbours, retail traders, schools, and other institutions), in larger domestic markets in urban centres, and in regional and international markets. For example, farmers in northern Tanzania and eastern and southwestern Uganda were producing red-mottled beans for sale in Nairobi and other urban centres in Kenya. In the Rift valley region of Ethiopia, farmers exported over 90% of navy beans. In Madagascar, farmers were producing the large white bean mainly for export, and in eastern Congo, farmers produced beans for sale to neighbouring Rwanda and Kinshasa.

Preferences for bean types also differed among markets, countries, and regions and no one variety could meet the diversity of market needs. In response to market demands and consumption preferences, production priorities differed among countries. To respond to these challenges, a new decentralised breeding strategy was developed in mid-2000. The overall strategy was to develop breeding programmes for the seven most important market classes following participatory approaches (table 1). In addition, the strategy proposed developing universal bean cultivars that have wider regional and international market appeal, which would serve as a basis for commercial seed production and eventually catalyse private research, breeding, and screening efforts for the benefit of people in this region. For each programme, breeding objectives and methods were defined, and the germplasm requirements to meet breeding goals, major outputs, indicators, milestones, activities, lead NARS, collaborating partners, and test sites were identified and described. Lead NARS were selected on the basis of the importance of a particular market class in their country, an expressed interest in providing regional leadership, and the presence of other comparative advantages. Collaboration in each programme was open to all NARS, farmers, nongovernmental organisations, seed companies, processors, exporters, and other stakeholders. Test sites were selected to represent the major bean-growing environments for each market class.

Table 1. ECABREN's Breeding Programmes, 2001

PROGRAMME	Production (ha)	Priority constraints*	Programme Leader	Collaborators
PROGRAMME 1. Red mottled	740,000	ALS, Anth/RR, low N and P, drought, BSM	Uganda	Kenya, DR Congo, Rwanda, Madagascar, Tanzania, Sudan
PROGRAMME 2A. Large red kidneys	350,000	ALS, Anth/RR, low P and N, Bruchids	Tanzania	Ethiopia, Rwanda, Kenya, Madagascar, Uganda, Burundi, Sudan
PROGRAMME 2B. Small and medium reds	670,000	Rust, ALS, RR, low P and N	Ethiopia	Rwanda, Burundi, Kenya, Uganda, Tanzania, DR Congo, Madagascar
PROGRAMME 3. Cream 3 A. Pinto 3 B. Sugars/cranberry 3 C. Carioaca	360,000	Pinto : Rust, CBB Sugar : Rust, CBB, HB, ALS, low N and P, Bruchids	Kenya Congo Ethiopia	Kenya, Ethiopia, Uganda, Madagascar, DR Congo, Rwanda
PROGRAMME 4. Climbers	Less than 100,000	Anth., ALS, Aschochyta, BCMV, RR, HB, low P and N, drought	Rwanda	Burundi, DR Congo, Kenya, Uganda
PROGRAMME 5. Snaps 5A. Bush 5B. Climbers 5C. Runner Climbers		Rust, RR, ALS, BCMV, Anth., BSM, thrips and nematodes	5a. Uganda 5b&C: Kenya	Kenya, Uganda, Tanzania, Ethiopia, Madagascar, Burundi
PROGRAMME 6A. Navy	310,000	Rust, CBB, ALS, Anth, drought, low P and N, BSM	Ethiopia	Kenya, Sudan, Uganda, Tanzania, DR Congo
PROGRAMME 6B. Large white kidney	220,000	Rust, ALS, Anth, low N and P	Madagascar	Tanzania, DR Congo
PROGRAMME 7. IIIa. Yellow IIIb. Brown IIIc. Tan	380,000	ALS, Anth/CBB, RR, rust, HB and low N and P	DR Congo	Angola, Tanzania, Kenya, Madagascar, Sudan
PROGRAMME 8 Parental source Nurseries		ALS, Anth, RR, Rust, Low N, pH and P	Ciat-Nairobi	ALL
BILFA		Low N ,Low P and Low pH	DR Congo	ALL
BIWADA		Drought earliness	Tanzania	ALL
Africa total	about 4 million ha			

*Anth=anthracnose; ALS= angular leaf spot; RR= root rot; P=phosphorus; N= nitrogen; CBB=common bacterial blight; HB=halo blight; BSM=bean stem maggot; a '/' between two constraints indicates equal importance.

Responsibilities for key partners were also defined. The main responsibilities for NARS are assembling germplasm, crossing, selecting for resistance to multiple constraints from segregating populations, nurseries, and advanced lines in collaboration with farmers and other stakeholders. They are also responsible for distributing populations and advanced lines to other NARS, maintaining breeders for released varieties, developing linkages with formal and informal seed multipliers, releasing varieties, promoting new varieties and technologies, and maintaining a self-monitoring and evaluation scheme.

Tasks for regional breeders include assembly of germplasm resources to support programmes; maintaining back-up crossing programmes; distributing segregating populations, advanced lines, and nurseries to NARS; assisting NARS in developing crossing programmes and implementing breeding schemes; training; maintenance of parental source nurseries; and co-ordinating and monitoring regional breeding programmes.

In this strategy, the role of CIAT is to provide genetic resources and technical support to regional programmes (ECABREN and SABRN); train partners in advanced breeding techniques, including marker-assisted selection and participatory breeding; develop molecular markers for major constraints, especially angular leafspot, anthracnose, bean common mosaic virus, and common bacterial blight; provide support in evaluation of biotic and abiotic constraints; design, implement, monitor, and evaluate socio-economic studies and supervision of graduate students. The strategy was approved by the ECABREN steering committee in December 2000 and is now operational.

Progress of breeding programmes

Six multiple-constraint nurseries (MCN) were created from single, three-way, double and complex crosses among selected parents of diverse origins. Both inter-genepool and intra-genepool crosses were made in breeding programmes at Cali (Colombia) and at Kawanda (Uganda) and Kabete (Kenya). The segregating populations were advanced to F₅ at Kabete under moderate pressure for anthracnose, angular leafspot, and rust (F₂ and F₃), BCMV (F₄), and rust and drought (F₅). The F₄ and F₅ progenies were separated into priority market classes, as shown in table 1.

Table 2 shows the number of F₅.F₁-derived lines of the 12 market classes with tolerance to two or more biotic constraints selected from the segregating populations during the short rain (October 99-Feb 2000) and long rain seasons (April-August 2000). These preliminary results show that, while progeny of the carioca seed type had the highest yield potential, considerable potential exists for further selection in most seed types. Selections with adequate seed were distributed to the respective lead NARS in October 2000 for evaluation in preliminary yield trials and to confirm resistance to biotic and abiotic stresses. Further screening for angular leafspot, anthracnose, and root rot was started using artificial inoculations in the Kawanda screen house late in 2000. Screening for tolerance to low soil P was started in Kakamega (Kenya), soil acidity at Mulungu (Congo), and low soil N at Arusha (Tanzania) during the short rain season (March-June 2001).

Table 2. Yield of Bean Lines Selected from Segregating Populations at Kabete, Kenya, 2000

Market class	Total entries	Selected progenies	Yield range (kg/ha)	Mean yield (kg/ha)	Network country responsible for eval.
Red mottled	927	227	121-4000	1873	Uganda
Red kidney	872	253	347-3814	1740	Tanzania
Small/medium red	103	82	390-3787	1615	Ethiopia
Navy	135	78	40-4185	1892	Ethiopia
Carioca	184	87	785-4734	2557	Ethiopia
Large white	129	5	691-2735	1326	Madagascar
Sugar/cranberry	435	59	410-3722	1923	DR Congo
Yellow/green	50	35	185-2963	1237	DR Congo
Brown/tan	355	109	267-4555	2265	DR Congo
Pinto	113	47	236-3761	1982	Kenya
Purple	491	327	108-3691	1520	open
Black	127	60	433-4000	2198	open

CONCLUSION

The new programmes are now in operation in seven ECABREN countries. Breeding materials with resistance to multiple constraints have been distributed and are in preliminary yield trials in many countries. These will expose them to a wider range of production constraints than is possible for one country and also increase the possibility of identifying those with specific and general adaptation. This strategy is expected to increase efficiency and reduce costs, since the individual national programmes do not have to develop full programmes for all important bean classes. These can be obtained from member NARS in the region. It also allows for specialisation in the development of new cultivars. It is therefore expected that the new cultivars developed will have wider market appeal and will better meet the requirements of bean growers.

BREEDING FOR RESISTANCE TO ANGULAR LEAF SPOT IN DRY BEANS IN SOUTH AFRICA

M. M. Liebenberg and A. J. Liebenberg

ABSTRACT

Angular leaf spot (ALS), caused by Phaeoisariopsis griseola, is one of the most important fungal diseases of dry beans (Phaseolus vulgaris) in Southern Africa and causes considerable yield and quality losses in the more humid production areas. The purpose of this study was to identify sources of ALS resistance for use in local breeding programmes. To assess the ALS reaction of differential lines and other important cultivars to different pathotypes of P. griseola, leaf area covered by lesions, combined with defoliation, was rated in the field and greenhouse. Particular note was also made of cultivars exhibiting field resistance, adult plant resistance, or tolerance to the disease. Crosses to combine different sources of ALS resistance, as well as ALS and rust resistance, have been made.

RÉSUMÉ

La maladie des taches anguleuses du haricot, provoquée par Phaeoisariopsis griseola, est l'une des principales maladies fongiques du haricot grains (Phaseolus vulgaris) en Afrique australe. Elle nuit considérablement à la qualité et au rendement dans les zones de production les plus humides. L'objectif de la présente étude était d'identifier des sources de résistance aux taches anguleuses afin de les utiliser dans des programmes de sélection locaux. Pour évaluer la réaction à la maladie des taches anguleuses de différentes lignées et autres cultivars importants aux différents pathotypes de P. griseola, la surface foliaire qui présentait des lésions ainsi que la défoliation ont été mesurées en champ et en serre. On a pris particulièrement note de cultivars montrant une résistance en champ, une résistance de plante adulte ou une tolérance à la maladie. Des croisements destinés à associer différentes sources de résistance aux taches anguleuses, ainsi qu'aux taches anguleuses et à la rouille, ont également été réalisés.

INTRODUCTION

Angular leaf spot (ALS), caused by *Phaeoisariopsis griseola*, is one of the most important fungal diseases of dry beans (*Phaseolus vulgaris*) in Southern Africa. It can cause considerable losses in the more humid production areas, which include Tanzania, Malawi, Mozambique, and the eastern parts of South Africa: KwaZulu-Natal, the Eastern Cape and Mpumalanga provinces, where small-scale farmers are particularly numerous and dry beans are regarded as a very important commodity.

ALS also causes sporadic but serious damage in other production areas when conditions are exceptionally wet. The effect of the disease is most apparent during pod fill. Loss of photosynthate due to lesions, chlorosis, and defoliation (a depleted source) leads to discolouration of seeds and to reduced mass and size, thus affecting not only yield, but also quality. Upper pods fail to develop, becoming shrivelled and dry. Losses are particularly serious due to the combined effect of ALS, rust, and ascochyta blight. Spraying with suitable chemicals can control these diseases to a limited degree, but it is costly and time consuming. The most effective control is the use of resistant cultivars, but all large-seeded cultivars (by far the most popular type) are very susceptible to ALS in South Africa.

The purpose of this study was to identify suitable sources of ALS resistance and to use them in backcross (BC) breeding programmes. This was originally a national project for South Africa but has been extended to include other SADC countries as a result of a grant from the Southern Africa Bean Research Network (SABRN).

METHODS

The research has been conducted along two parallel lines. On the one hand, single conidium isolates were tested in the glasshouse, initially using the old differential cultivar set comprising Montcalm, Seafarer, BAT 332, Pompadour Checa, G 5686, Cornell 49242, A 339, and BAT 1647 (Correa-Victoria, 1987) and, later,

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the new international set, comprising Don Timoteo, G11796, Bolon Bayo, Montcalm, Amendoin, G 5686, PAN 72, G 2858, Flor de Mayo, Mexico 54, BAT 332, and Cornell 49242 (CIAT, 1996a). These were supplemented by other important local cultivars and potential sources of resistance.

Simultaneously, the same cultivars were planted in the field under conditions of high disease pressure. In both instances, ratings were made of leaf area covered by lesions, combined with defoliation, using a modified version of the CIAT one-to-nine scale (Liebenberg, 1996). South African germplasm, as well as additional cultivars obtained from CIAT-Colombia and CIAT-Uganda, were also evaluated in the field. Particular note was made of cultivars exhibiting field resistance, adult plant resistance, or tolerance to ALS. This methodology is still being applied, although inoculations are now limited to isolates attacking previously resistant cultivars.

RESULTS: SOURCES OF RESISTANCE

When the work was started in 1992, small-seeded cultivars of Meso-American origin were generally resistant in South Africa, and also showed resistance to most isolates from SADC countries. Large-seeded cultivars were all susceptible. Results of characterisations of pathotype have been reported elsewhere (Boshoff et al., 1996; Liebenberg, and Liebenberg et al., 1996-1998). Since then, small-seeded and other previously resistant lines have been reported susceptible in Malawi (compare National Bean Programme annual reports 1992 and 1996-97) and since 1998, have shown increasing amounts of disease in South African field trials. However, appreciable yield losses have not yet been reported here for small-seeded lines. Isolates collected from cultivars of Meso-American origin have proved difficult to inoculate in the greenhouse due to poor sporulation. When inoculations were successful, all of the old set of differentials were susceptible. On the new set, Meso-American-type isolates have a broader virulence, as do the Andes type, but they do not attack all cultivars.

The large-seeded cultivars CAL 143, G 5686, AND 277, AND 935, AND 905, and DRK 85 have exhibited good to moderate resistance, especially in the field, as have some small-seeded cultivars (in particular, Mexico 54, Ecuador 299, PAN 185, BAT 1569, BAT 300, and BAT 434). The resistance of Ica Pijao complements that of CAL 143. We also confirmed the complementary nature of the resistances of G 5686, Mexico 54, BAT 332, and Cornell 49242 reported by CIAT (CIAT, 1996b), with the implication that the combined resistance of these four cultivars will give resistance to all known races (Liebenberg, 1998). A 286 (known as 'Mkuzi' in South Africa and 'Kambidzi' in Malawi) has useful resistance but is not resistant to the Meso-American-type pathotypes.

In a recent search to find resistance to the more widely virulent pathotypes attacking small-seeded beans of Meso-American origin, 10 additional large-seeded lines were obtained from CIAT-Colombia. These were planted in the field during the past season. Only four of these, namely AFR 735, AFR 645, AND 279, and CAL 173, were free of ALS and will be tested in the greenhouse.

RESULTS: BREEDING PROGRAMMES

Using some of the above-mentioned resistant lines as donor parents, backcross breeding programmes have been undertaken to incorporate vertical resistance into locally well-adapted popular cultivars. These are in various stages of progression, from BC 1 to BC 4 F₂. Besides early greenhouse screening, selections are made in the field (at both hot-spot disease localities and in important production areas) for disease resistance, yield, and adaptation. Where possible, attempts are also being made to incorporate some field resistance, adult plant resistance, and/or tolerance to ALS.

As resistance to a single disease is not sufficient to provide the farmer with a reliable cultivar requiring a minimum outlay on chemical treatment, we are striving to achieve multiple disease resistance. Rust is more widespread than ALS in South Africa, occurring in all the major production areas. Even in areas where both diseases are severe, yield loss as a result of rust may be higher than that caused by ALS, due to the earlier onset of rust. The effect of the rust is often masked by the onset of ALS, followed by defoliation. This can be misunderstood to be solely due to ALS. Some degree of rust resistance is present in all local cultivars, but in many cases, this is not sufficient. For this reason, separate breeding programmes are devoted to rust. Improved rust and ALS lines, containing the rust-resistance gene Ur-11 (from a small-seeded background) and the ALS resistance from CAL 143, respectively, have been combined at BC 4 in a large-seeded red-speckled sugar and Calima background. Crosses to combine some of the different ALS-resistant sources in different backgrounds have also been made specifically for small-scale farmers.

It is difficult to preserve dual resistance over several backcrosses. In the process of gene pyramiding, it has been important to improve the resistance of a popular, well-adapted, and high-yielding cultivar to each disease *separately* by means of backcrossing, rather than to cross two resistant sources with the recurrent parent and then to backcross. It is then relatively straightforward to combine the two types of resistance (figure 1). The same applies to the pyramiding of genes giving resistance to different pathotypes of a single pathogen.

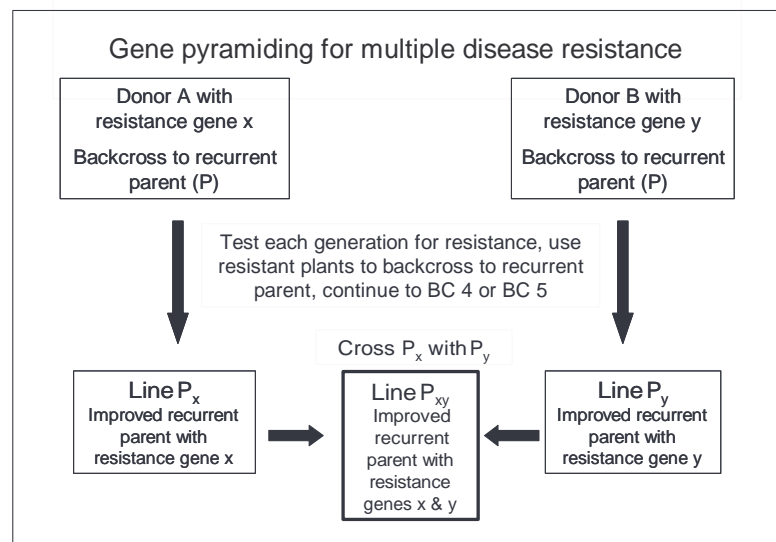


Figure 1. Gene pyramiding for multiple disease resistance

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BACKCROSS BREEDING TO IMPROVE RESISTANCE TO COMMON BLIGHT IN SOUTH AFRICAN BEAN CULTIVARS

D. Fourie, A. J. Liebenberg, and L. Herselman

ABSTRACT

*Dry beans are an important leguminous food crop grown in South Africa. Approximately 58,000 tons are produced annually by commercial and small-scale farmers. Common bacterial blight, caused by *Xanthomonas axonopodis* pv. *phaseoli* is a major disease, limiting dry bean production. In Eastern and Southern Africa it has been reported in 19 of the 20 bean-producing countries and is considered one of the five most widespread and important constraints across sub-Saharan Africa. Chemical control with copper sprays only reduces secondary infection and does not offer an effective and economic alternative. All locally grown commercial cultivars are moderately to highly susceptible to common blight, and the improvement of cultivars, by introducing stable resistance, is therefore the main objective of the dry bean research programme at the Agricultural Research Council-Grain Crops Institute (ARC-GCI) in South Africa. Progress in improving CBB resistance in Kranskop (red-speckled sugar bean) has had limited success. Only moderate levels of resistance were observed in lines with acceptable seed colour, and other sources of resistance are being exploited. Resistant lines with seed colour unacceptable for the South African market can, however, be made available to other African countries, where a wider range of market classes are planted.*

RÉSUMÉ

*Les haricots grains constituent une culture légumineuse vivrière importante en Afrique du Sud. Grands et petits exploitants en produisent annuellement environ 58 000 tonnes. La brûlure bactérienne, due à *Xanthomonas axonopodis* pv. *phaseoli*, est l'une des principales maladies qui limite cette production. En Afrique orientale et australe, cette maladie, constatée dans 19 des 20 pays producteurs de haricots, est considérée comme l'une des cinq contraintes les plus largement répandues en Afrique subsaharienne. Les pulvérisations de cuivre ne réduisent que l'infection secondaire et n'offrent pas une solution efficace et économique. Tous les cultivars commerciaux cultivés localement sont de modérément à extrêmement sensibles à la brûlure bactérienne et l'amélioration de cultivars, au moyen de l'introduction d'une résistance stable, représente donc le principal objectif du programme de recherche sur le haricot grains au Agricultural Research Council-Grain Crops Institute (ARC-GCI) en Afrique du Sud. L'amélioration de la résistance à la brûlure bactérienne du Kranskop (haricot du Cap à marbrures rouges) n'a connu qu'un succès limité. Des lignées aux graines de couleurs acceptables n'ont révélé que des niveaux de résistances modérés. Les lignées résistantes aux graines de couleurs inacceptables pour le marché sud africain peuvent être toutefois proposées à d'autres pays africains où l'on cultive un plus large éventail de catégories commerciales.*

INTRODUCTION

Dry beans are an important leguminous food crop grown in South Africa, and approximately 58 000 tons are produced annually by commercial and small-scale farmers (Coetzee, 2000). Common bacterial blight (CBB), caused by *Xanthomonas axonopodis* pv. *phaseoli* is a major disease, limiting dry bean production in South Africa. It also ranks near the top of the list of bean-production problems throughout most of the world (CIAT, 1985) and occurs in temperate, subtropical, and tropical regions (Singh, 1991), causing severe damage under favourable environmental conditions. In Eastern and Southern Africa it has been reported in 19 of the 20 bean-producing countries (Allen, 1995) and is considered one of the five most important and widespread constraints to bean production in sub-Saharan Africa (Gridley, 1994). Although common blight is widely distributed, and estimated losses of up to 45% have been reported (Yoshii, 1980), losses as a result of the disease are not well documented.

The common blight pathogen is seed-borne, and contaminated seed is considered the primary source of inoculum (Cafati and Saettler, 1980; Gilbertson et al., 1990; Arnaud-Santana et al., 1991; Opio et al., 1994; Allen et al., 1998). Planting of pathogen-free seed is an important primary method of control in South Africa, but the use of disease-free seed alone does not guarantee freedom from the disease. Additional cultural practices are needed, such as removing, destroying, or deep ploughing of bean debris, effective weed control, and crop rotation (Allen et al., 1998; Schwartz and Otto, 2000). Copper-based bactericides are generally used to protect foliage against *the pathogen* and to control secondary spread. The effectiveness of chemical control of common blight, however, is considered limited, with usually minimal yield increases (Saettler, 1989).

Genetic resistance is considered to be the most effective strategy to control common blight in beans (Rands and Brotherton, 1925), but all locally grown commercial cultivars are moderately to highly susceptible. Improvement of cultivars, by introducing stable resistance, is therefore the main objective of the bacterial research programme at the Agricultural Research Council-Grain Crops Institute (ARC-GCI), South Africa.

Sources resistant to common blight, from the International Center for Tropical Agriculture (CIAT), were evaluated for resistance to local virulent strains of *X. axonopodis* pv. *phaseoli*. Highly resistant sources were identified in the lines XAN 159, Wilk 2, Wilk 4, and Wilk 6. XAN 159 was developed at CIAT from a *P. vulgaris* x *P. acutifolius* population, and resistance is controlled by one major and a few minor genes. The Wilk lines were developed at Cornell University, and although the exact pedigree and germplasm used are not known, they seem to have resistance genes from *P. vulgaris*, *P. coccineus*, and *P. acutifolius*, including XAN 159 or its sister lines (Singh and Muñoz, 1999).

BREEDING FOR RESISTANCE

Material and methods

XAN 159 and Wilk 2 were selected for backcross breeding to improve the resistance of Kranskop (speckled sugar bean) and Teebus (small white canning bean). These cultivars were selected on the basis of their commercial value.

Crosses were made between the resistant donor (pollen) parents (XAN 159 and Wilk2) and the recurrent susceptible parents (Kranskop and Teebus). First trifoliolate leaves of plants from the F₁ generation were inoculated with a bacterial suspension containing approximately 10⁸ CFU/ml water, using the multiple needle-puncture method (Andrus, 1948). Leaves were rated for infection 10 days after inoculation on a scale from 1 to 9 (1 being highly resistant and 9 being highly susceptible). Susceptible plants (rated 4-9) were discarded and resistant plants (rated 1-3) were selected for backcrossing, with emphasis on testing leaf-blight resistance. The process of backcrossing was continued until a total of five generations of backcrossing and testing were completed. Selected lines will be evaluated in the field by the breeder for yield and other agronomic traits.

1	Recurrent parent (Kranskop; Teebus)	X	Donor (XAN 159, Wilk 2)
2	Test - BC ₁		
3	Test - BC ₂	Evaluate F ₂ in field	
4	Test - BC ₃	Evaluate F ₂ in field	
5	Test - BC ₄	Evaluate F ₂ in field	
6	Test - BC ₅		
7	Test - select resistant F ₁ plants		
8	F ₂ single-plant progeny rows, identify homozygous rows		
9	Increase seed—evaluate resistance		
10	Compare lines—yield & adaptation—select best		
11	Replicated trials—compare with recurrent parent		
12	Further evaluation or release		

Figure 1. Scheme of backcross programme

While the process of backcrossing was continuing in the greenhouse, segregating populations from earlier backcrosses were planted in field trials at Potchefstroom and evaluated for resistance. Teebus was planted throughout the plot as susceptible check. First or second trifoliolate leaves of each plant were inoculated using the multiple-needle method, followed by spray-inoculating plants weekly using the backpack sprayer. Each plant was rated separately and single-plant selections made. Spray-inoculated canopies were evaluated periodically from when first symptoms appeared on susceptible checks until the crop matured. Single-plant progeny rows were planted at Makhatini in the winter and inoculated and rated similarly. Single plants were once again selected and planted in progeny rows at Potchefstroom in summer, and the process continued until single rows with uniform high levels of resistance could be selected.

Marker-assisted selection

In addition to phenotypic disease reaction, molecular markers were used during the latter stage of the study to confirm transfer of resistance to local cultivars. XAN 159 contributes two independent quantitative trait loci (QTL) with major effect for CBB resistance. Sequence characterised amplified region (SCAR) markers linked to these QTL are available for DNA marker-assisted breeding (Miklas et al., 2000). The markers, SU91 and BC420, were tested on resistant lines from segregating populations. SCAR marker SU91 is linked with a major QTL on linkage group B8, and marker BC420 with a QTL on linkage group B6. In addition to these markers, SCAR marker SAP6, derived from a resistant line GN Nebr. Sel#27, was also included. GN Nebr. Sel#27, which contributes two major QTL, is internationally used in breeding programmes as a source of common blight resistance.

Table 1. SCAR Markers Used to Screen Segregating Populations

Primer	Sequence (5'-3')	Linkage Group	Source
SU91-1	CCACATCGGTTAACATGAGT	B8	XAN 159
SU91-2	CCACATCGGTGTCAACGTGA		
BC420-1	GCAGGGTTCGAAGACACACTGG	B6	XAN 159
BC420-2	GCAGGGTTCGCCCAATAACG		
SAP 6-1	GTCACGTCTCCTTAATAGGTA	B10	GN Nebr. sel#27
SAP 6-2	GTCACGTCTCAATAGGCAA		

Source: Miklas et al. (2000).

Primers were synthesised based on the primer sequences of the SCAR markers, SU91, BC420, and SAP6, as indicated in the literature. DNA was isolated using the method of Graham et al., (1994). Multiplex PCR reactions using all the SCAR primers were performed at a 2mM MgCl₂ and 58°C annealing temperature, using standard PCR conditions.

RESULTS

Improvement of small white canning beans

Resistance from XAN 159 and Wilk 2 were successfully transferred to the cultivar Teebus in two separate backcross programmes, which have now both progressed to the completion of BC₅. Approximately 98% of Teebus has been recovered with the addition of CBB-resistance genes. Progenies of these crosses were evaluated in field trials in Potchefstroom during the past season, and single plants with high levels of resistance were selected. Single-progeny rows are currently being evaluated in winter trials in KwaZulu/Natal. Homozygous rows will be included in yield trials during the coming season, followed by replicated trials and comparison with the recurrent parent. Promising lines with satisfactory canning quality will be released for commercial use.

Improvement of large seeded red speckled sugar beans

Progress in improvement of CBB resistance in Kranskop (red speckled bean), has had limited success. Resistance was successfully transferred from both XAN 159 and Wilk2. Only moderate levels of resistance were, however, observed in lines with acceptable seed colour. Other sources of resistance are being exploited for use in this backcross programme.

Table 2. Lines from Segregating Populations Used to Test Effectiveness of Markers

Line number	Line name
Teebus	Small white canning bean (<i>Phaseolus vulgaris</i> —susceptible parent)
Kranskop	Red-speckled sugar (<i>P. vulgaris</i> —susceptible parent)
XAN 159	Resistant line (<i>P. acutifolius</i> x <i>P. vulgaris</i>)
GN Nebr.#1 sel.27	Resistant line (<i>P. vulgaris</i> x <i>P. acutifolius</i>)
Wilk 2	Resistant line (sources unknown)
Wilk 4	Resistant line (sources unknown)
Wilk 6	Resistant line (sources unknown)
PC 1465-BC ₅ (1.1.1)	Backcross inbred line (Teebus/XAN 159)
PC 1465-BC ₅ (2.1.2)	Backcross inbred line (Teebus/XAN 159)
PC 1470-BC ₂ 1	BC ₂ line (Kranskop/XAN 159)
PC 1470-BC ₂ 3.1	BC ₂ line (Kranskop/XAN 159)
PC 1821-BC ₅ 22	Backcross inbred line (Teebus/Wilk 2)
PC 1821-BC ₅ 22	Backcross inbred line (Teebus/Wilk 2)

Field evaluations of earlier backcrosses

More than 200 single plants were originally selected from earlier backcross generations in the field at Potchefstroom. Final selections were made from the F₅ progeny rows planted in Makhatini (KwaZulu/Natal) during 1998. Field selections of Teebus backcrosses judged to be homozygous for all important properties were tested for canning quality, and yields of 78 of the best lines were evaluated in four different localities for two consecutive years. These trials will run for another season, after which successful lines will be entered in the National Cultivar Trials and seed made available to farmers. The same procedure will be followed with progeny of the final backcrosses.

Marker-assisted selection

Both markers SU91 and BC420 (derived from XAN 159), as well as marker SAP6 (GN Nebr. Sel. #27), were successfully used to confirm resistance in selected lines. Marker SAP6 was present in Teebus and Kranskop and could have been introduced by parents used in developing these cultivars. Advanced Teebus lines developed through backcross breeding with XAN 159 had both SU91 and BC402 markers (figures 2 and 3). Greenhouse results indicated that these lines had higher levels of resistance than XAN 159, which could be explained by combined resistance from GN Nebr. #1 sel. 27 and XAN 159.

Both SU91 and BC420 markers are present in Wilk 2, 4, and 6 (figure 4), which indicates that resistance from XAN 159 (or the same source) was used in developing these lines. They have, however, higher levels of resistance against local isolates, which may indicate that additional sources of CBB resistance were used in gene pyramiding. PCR studies from BC₅ lines derived from backcrosses between Wilk 2 and Teebus as recurrent parent indicated that both markers SU91 and BC420 (XAN 159 derived) were transferred to these lines (figure 4).

XAN 159-derived Kranskop lines only had moderate levels of resistance when tested in the greenhouse. PCR studies indicated that the BC402 marker was absent in these lines (figure 2). This marker is near the *V* locus conditioning purple flower colour (Miklas et al., 2000), resulting in resistant plants exhibiting seed unacceptable for the market; however, the presence of marker BC420 seems important to obtain high levels of resistance.

Problems encountered

1. The most serious problem with breeding for CBB resistance is the instability of resistance. Often after a number of generations of selfing, CBB-resistant lines continue to segregate. The cause of the instability is unknown.
2. Resistant lines developed from crosses between the donor parent and large-seeded red-speckled recurrent parent are often not of an acceptable commercial seed type (purple speckled). The use of molecular markers has indicated that resistance and flower colour are closely linked.

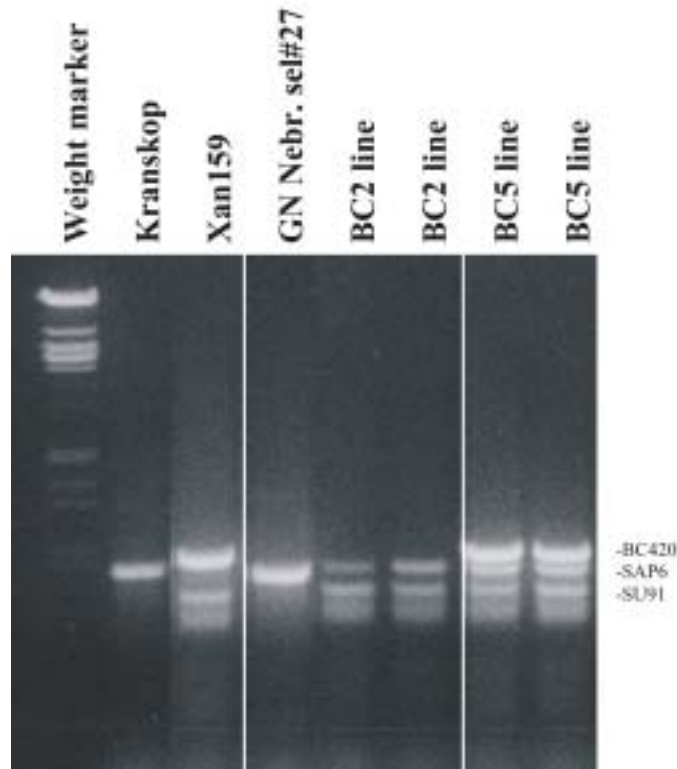


Figure 2. Screening of parental lines (Kranskop and Xan159) and backcross lines (BC₂ and BC₅) for CBB resistance using SCAR markers BC420, SAP6, and SU91

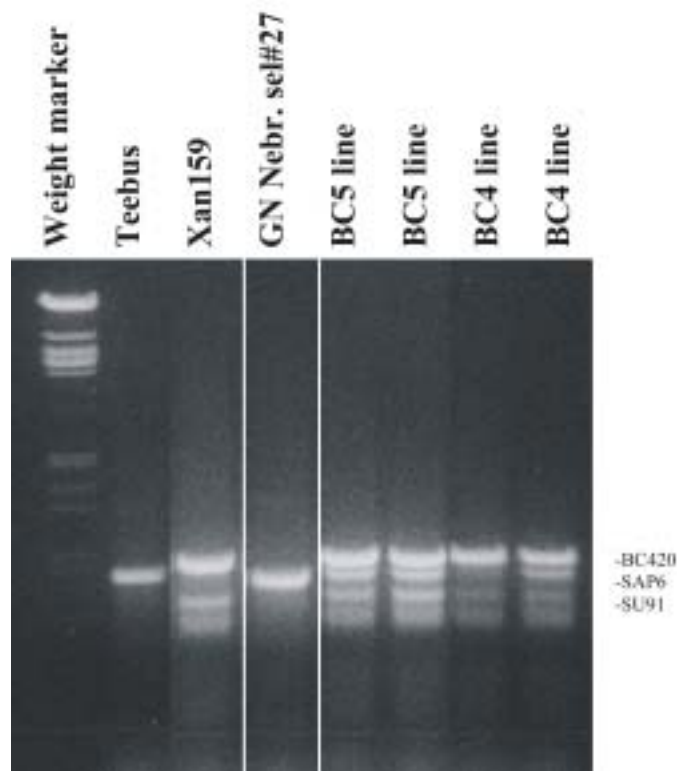


Figure 3. Screening of parental lines (Teebus and Xan159) and backcross lines (BC₄ and BC₅) for CBB resistance using SCAR markers BC420, SAP6, and SU91

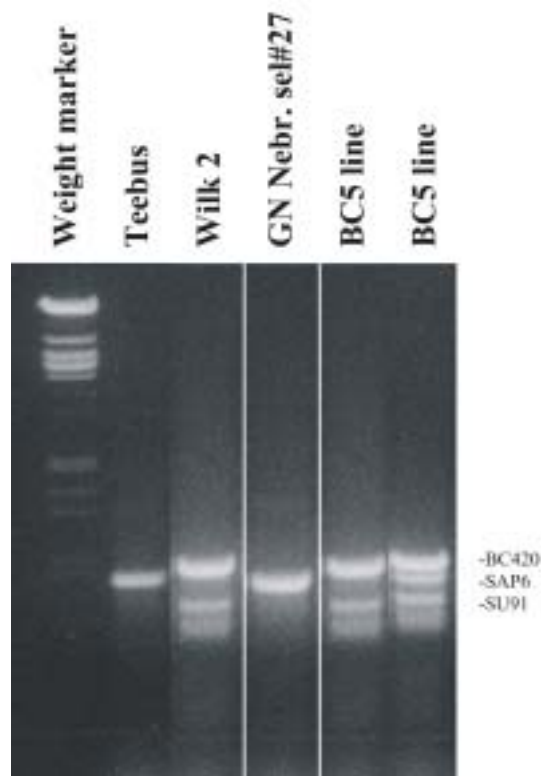


Figure 4. Screening of parental lines (Teebus and Wilk 2) and backcross lines (BC₅) for CBB resistance using SCAR markers BC420, SAP6, and SU91

Future prospects

1. The search for new sources of resistance will be continued and it will further be desirable to pyramid resistance genes to the same pathogen into a single cultivar in order to achieve more stable resistance. Use of marker-assisted selection will contribute considerably when pyramiding is attempted.
2. Additional sources of CBB resistance are being exploited to improve resistance of large-seeded cultivars. Lines with CBB and drought resistance have been developed through inter-specific crosses between *P. vulgaris* and *P. acutifolius*. PCR studies indicate that these lines contain a different source of resistance than XAN 159. The Vax lines developed by CIAT also show promising resistance, especially Vax 4 (white flower). Molecular markers will, however, have to be developed when pyramiding of different resistance genes is attempted.
3. XAN 159-derived Teebus lines have been successfully combined with rust-resistant lines developed in an independent breeding programme in order to develop a cultivar resistant to multiple diseases. These lines are currently being evaluated in field trials. Resistance to rust and common blight will also be combined into a single cultivar once CBB resistance of large-seeded cultivars has been improved.
4. Attempts are being made to combine lines with resistance to common blight and halo blight.
5. Crosses are currently being made to improve resistance to bacterial brown spot in a backcross programme. CBB-resistant Teebus lines (XAN 159 derived) are being used as recurrent parent in these crosses.

Possible contributions to the SADC community

1. Some of the progeny from BC₁ to BC₃ which have been selected in the field as offshoots of the backcrossing programme exhibit excellent desirable properties, such as high yield and disease resistance, but are not suitable for use because of a seed color not acceptable for the market. Some of

these lines might be acceptable in other African countries where a greater variety of seed types are planted. Seed from these lines are available for interested parties.

2. ARC-Grain Crops Institute is able to

- multiply and distribute the best sources of resistance to SADC countries
- evaluate breeders' lines and varieties for resistance under field and greenhouse conditions
- distribute segregating material from backcross programmes to SADC countries
- make initial crossings, first backcrosses, and screening for resistance in the progeny of adapted cultivars from resistant SADC and South African lines

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CLIMBING BEANS IN RWANDA: DEVELOPMENT, IMPACT, AND CHALLENGES

Augustine Musoni, R. Buruchara, and P. M. Kimani

ABSTRACT

Beans (Phaseolus vulgaris L.) are the second major contributor of dietary protein in East and Central Africa. With an adoption rate of 50% among farmers just 10 years after their introduction, improved climbing beans are fast replacing the bush type, raising on-farm productivity and contributing significantly to the GDP in Rwanda. Due to their yield advantage of 150% to 300% and better disease resistance, climbing beans have shown great potential for intensified production in other densely populated, humid, root-rot infested highlands in southern Uganda and central and western Kenya, as well as northern Tanzania, where improved varieties of climbing beans released in Rwanda have been introduced in recent years. The economic returns from growing climbers have encouraged farmers to invest in species like Leucaena and Calliandra to overcome staking problems, which has, at the same time, enabled farmers to exploit other values of the species, such as soil protection, soil improvement, fodder for ruminants, or a source of cooking fuel. Current research by Institut des Sciences Agronomiques du Rwanda (ISAR) aims at developing climbing beans with red and red-mottled seed, having multiple disease resistance to meet the internal, regional, and international market demand.

Keywords: climbing beans, intensified production, agroforestry, partnership, market

RÉSUMÉ

En Afrique orientale et centrale, le haricot (Phaseolus vulgaris L.) occupe la seconde place en tant que source de protéines dans le régime alimentaire. Adoptée par 50 % des cultivateurs dans l'espace d'une dizaine d'années après son introduction, une variété améliorée de haricot volubile est en train de remplacer rapidement le haricot nain, augmentant la productivité des exploitations et contribuant de manière importante au PIB du Rwanda. Du fait de son rendement supérieur de 150 à 300 % et d'une meilleure résistance aux maladies, le haricot volubile a révélé un formidable potentiel pour une production intensifiée dans d'autres régions densément peuplées. Il s'agit des hautes terres humides mais infestées par le pourridié au sud de l'Ouganda, au centre et à l'ouest du Kenya ainsi qu'au nord de la Tanzanie, où des variétés améliorées de haricots du Rwanda ont été introduites au cours de ces dernières années. Les retombées économiques de la culture des variétés volubiles ont encouragé les agriculteurs à investir dans des espèces comme Leucaena et Calliandra pour surmonter les problèmes de tuteurage, ce qui leur a en même temps permis de profiter d'autres avantages de ces espèces tels que la protection et l'amélioration des sols, la fourniture de fourrage pour les ruminants ou de combustible pour la cuisson. La recherche en cours réalisée par l'Institut des Sciences Agronomiques du Rwanda (ISAR) a pour objectif de développer des variétés de haricots volubiles aux graines rouges et tachetées de rouge résistantes à plusieurs maladies, afin de répondre à la demande du marché interne, régional et international.

Mots clés : haricot volubile, production intensifiée, agroforesterie, partenariat, marché

INTRODUCTION

Nearly all Rwandans and over 100 million people in Africa, mostly the resource-poor rural and low-to-medium income earners in urban areas, consume the common bean (*Phaseolus vulgaris L.*). It is the leading

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staple after maize in East and Central Africa. About four million hectares of beans are cultivated in Africa annually (CIAT, 1995), with a production of two million tons (Chrispeels and Savada, 2003).

Beans are eaten as cooked dry or fresh grain, green leaves, or pods. A near-perfect food, they provide a cheap source of quality globulin proteins and micronutrients—iron, zinc, and vitamins—that enhance normal growth and development (CIAT, 1995; Graham, 1996). Bean consumption in Rwanda is estimated at 50 kg to 60 kg per capita, making it one of highest in the world (Londono et al., 1980). In Rwandan diets, beans contribute 84% of the pulse legume and 65% of all plant and animal protein. They are the *meat* of the poor (MINIPLAN, 1988). Although 20% of the beans produced in Rwanda are marketed (Wortmann et al., 1998), the country remains a net importer of the commodity.

Climbing beans

True climbing (or pole) beans (Types III and IV) have an indeterminate growth habit. Their stems are longer, more slender, and weaker than those of bush beans. They are able to twine and grow over two meters when the plant is appropriately staked. At some stages, flowering, pod formation, and filling, as well as maturation, occur simultaneously. This leads to staggered harvesting of leaves, pods, and grain, thus providing diversified nutrition and improved household food security throughout the growing season (Sperling et al., 1992). The twining, heavy branching, multiple lateral inflorescence system, and enhanced pod-load (up to 10 grains per pod) of the climbers are closely associated with their observed high yield potential of 3 to 5 tonnes/ha—three times more than that of bush beans. Their climbing habit creates unfavourable micro-niches for the development of fungal pathogens, which makes climbing beans generally more tolerant to fungal diseases than their bush counterparts.

These attributes more than compensate for the longer time climbing beans tend to take to attain full maturity (89 to 118 days in Rwanda), especially at higher altitudes (over 1700 meters above sea level).

Production environments

Climbing beans do well under the cool, fertile conditions of high-altitude areas (1400 m and 2300 m above sea level) with an optimal mean annual rainfall of 1000 mm to 2000 mm. In Rwanda there are six major agroecological zones (table 1) with these conditions, cutting across nine of the 11 provinces (Gisenyi, Ruhengeri, Byumba, Kibuye, Gikongororo, Cyangugu, Butare, Kigali Rural and Kibuye). The amount and duration of rainfall is the most important factor limiting production of climbing beans.

Table 1. Major Environments for Growing Climbing Beans in Rwanda

Serial No.	Name of zone	Altitude (masl)	Rainfall (mm)	Soil type
2	Impala	1400 - 1900	1300 - 2000	Heavy red, from basalts
3	Show Lake Kivu	1460 - 1900	1150 - 1300	Clay-loam surface soils
4	Lave Lands	1600 - 2500	1300 - 1600	Volcanic soils
5	Summit	1900 - 2500	1300 - 2000	Humic acid soils
6	Buberuka	1900 - 2300	1100 - 1300	Lateritic soils
7	Central Plateau	1500 - 1900	1100 - 1300	Different humic soils

Source: Adapted from Nyabyenda (1980).

Traditionally, climbing beans have been grown in the northeastern highlands of Rwanda's Ruhengeri and Gisenyi provinces since beans were domesticated three to four centuries ago (Debouck and Tohme, 1988), making it one of the oldest cropping systems in Africa (Allen and Edje, 1990).

Production systems

Multiple cropping systems are the most common practice in Rwanda. Climbing beans are grown along with other crops, mostly monoculture, especially at higher altitudes (2000 m to 2300 m above sea level). The banana-climbing-bean intercrop is the most compatible, but relay and mixed cropping with cereals, especially maize, are also common (Woolley et al., 1991). They are grown in two major seasons (A and B), with an off-season (C, May-August), which is usually planted in marshy lands.

In general, bean production in Rwanda is done under low levels of agrochemical sprays or fertiliser and minimal application of modern cultural practices, such as fallowing or crop rotation. There is little regard to row planting, and spacing and the sowing rate are usually higher than recommended (200,000 seeds per hectare). This is mainly due to scarce land (between 0.2 ha to 1.0 ha per household), as well as a lack of other resources: 95% of bean producers in Rwanda are the rural poor and underprivileged.

Production constraints

These production methods favour the accumulation of disease pathogens and insect pests, which cause continued yield losses over seasons. With little replenishment of essential plant nutrients (N, P, and K), soils lose fertility; the mean rate of application of inorganic fertilisers is estimated at only 4 kg/ha, about 1.3% of the optimal rate (Kelly et al., 2002). The application of organic soil amendments from animal sources, which is a more popular practice, is restricted by the small population of farm animals per household in the major areas of Rwanda where climbing beans are grown.

The most notable diseases of climbing beans are angular leaf spot (*Phaeoisariopsis griseola*) and root rot caused by a complex of soil pathogens (*Pythium* spp., *Fusarium solani* f. sp. *phaseoli*, *Rhizoctonia solani*, *Macrophomina phaseolina*, *Sclerotium rolfsii*, and *F. oxysporum* f.sp *phaseoli*) (Buruchara and Rusuku, 1992; Nderitu et al., 1997) and bean common mosaic virus (BCMV). Anthracnose (*Colletotrichum lindemuthianum*), ascochyta blight (*Ascochyta phaseolorum*), and halo blight (*Pseudomonas syringae* pv. *phaseoli*) are only important at higher altitudes (over 1800 m). The fungal diseases alone cause a loss of grain yield of 219,575 tons (US\$ 89 million/year) in Rwanda (Trumann and Graf, 1993). They are largely implicated in the decline in bean productivity from 1120 kg to 802 kg/ha between 1984 and 1990 (Sperling, 2001). Bean stem maggot (*Ophiomyia* spp.) and bruchids (*Acanthoscelides* spp. and *Zabrotes* spp.) are important field and storage insect pests of beans. However, the soil-related factors such as low N, P, pH, and moisture are the most important production constraints (Wortmann et al., 1999).

Other post-harvest constraints are socio-economic. Improved varieties that lack the desirable culinary (cooking time, taste, broth colour and keeping time, flatulence) and market attributes (seed colour and size, shape and mass) are the least accepted and adopted by farmers and consumers.

Lack of staking wood and other trellises leads to low adoption of climbing beans. Poor or no staking cuts the yield of climbing beans between 30% to 100%, depending on the variety and prevailing weather conditions. Type IV climbers are most affected by wet weather. Plants become severely diseased and pods and seed often rot or are tarnished.

VARIETY IMPROVEMENT

The Institut des Sciences Agronomiques du Rwanda (ISAR) was formed in the 1960s and 1970s, and as the importance and relevance of climbing beans became apparent, research was initiated to screen and improve local landraces or introduced varieties. The first improved climbing bean varieties—notably Cajamarica (from Peru); Wulma, C8, C10 (DRC); Sabre a rames (Belgium); Gisenyi 1 & 6, Urunyumba 1, 3 & 12, Rwerere 14, Var 54 and Var 18 (Rwanda); Bayo (Uganda) and Amarillo ouro (Angola), among others—were in use by farmers in the 1970s (Nyabyenda et al., 1980). But it was not until the 1980s, that ISAR and the International Center for Tropical Agriculture (CIAT) intensified breeding for improvement and the dissemination of climbing beans in Rwanda. Many superior varieties have been released to farmers since the mid-1980s and have replaced nearly all the old ones.

Problem

Despite its comparatively small size (260,000 km²), Rwanda is diverse in terms of geographical and geological features (relief, climate, and soil type). Specific zones and niches tend to have special biotic and abiotic factors that limit bean productivity. There are also special preferences for seed types among farmers, traders, and consumers. Farmers usually plant mixtures of multiple varieties (three to 27, with climbers on the lower end) and adjust them to suit their location, farms, homesteads, or even seasonal conditions (Allen and Edje, 1990; Sperling, 1990). Traders and urban consumers, on the other hand, prefer uniform single varieties because of premium prices and taste. The diverse ecological and socio-economic needs of the different users present a big challenge to research.

Objectives

The goal of research on climbing beans in Rwanda is within the framework of ECABREN's mandate: to contribute to sustainable improved food security, quality nutrition, and income earning through realisation of high productivity and commercialisation of beans. The specific objectives were to develop and provide to farmers and other end users high-yielding varieties of climbing beans that are tolerant to multiple production constraints and adapted to different agro-ecological zones and, in addition, having seed types that are acceptable to the different end users. The research also aimed at developing and promoting multiple ways of staking climbing beans, as well as strengthening partnerships that promote communication and the scaling up of sustainable climbing bean technologies among stakeholders.

METHODOLOGY

Collection and introduction

New climbing bean varieties are selected from three initial sources. The most common is by screening large numbers of locally collected landraces and introduced lines from international research centres, such as CIAT and regional research organisations (now under ECABREN) and obtaining those with promising yields and resistance to major diseases and pests. This is done in three stages of yield trials (YT): (1) preliminary (PYT), (2) intermediate (IYT), and (3) advanced (AYT). The trials are conducted on two ISAR stations, Rubona and Rwerere, which are representative of conditions in the mid- and high-altitude ecologies, respectively (table 2). IYTs are replicated and planted in a randomised complete block design and AYT in a balanced lattice design. A local farmers' variety, usually a mixture of three to 10 varieties, known as 'local mixture', and a released climbing variety are included as checks. The trials are planted in both seasons A and B of the year.

Table 2. Characteristics of Major On-Station Screening Sites of Climbing Bean Varieties in Rwanda

Site	Location	Altitude (masl)	Rainfall (mm)	Temp (°C)	Soil type	Soil pH
Rubona	South	1650	1171	18.9	Oxisol	5.0
Rwerere	North	2300	1166	15.6	Alfisol-ultisol	5.2

Fewer elite materials are then planted at many diverse sites on-farm in comparative multilocal trials (MLTs), in larger plots with fewer replicates (usually 5 m x 5 m with two replicates). MLTs are managed by researchers and farmers. They also serve as demonstration plots to many farmers in the area to show new agronomic management practices for climbing beans. At the same time, farmers retain seed of their preferred varieties, which provide a key link in the diffusion process.

Crossing

Another important source of new varieties is through crossing programmes. Released varieties that are deficient for certain traits, such as resistance to diseases, are improved by backcross-breeding and selection. Gamete and pedigree breeding and selection are used to improve varieties for resistance to multiple constraints. Elite lines that are stable (DSU) that emerge (at F₄ to F₉) are fed into the PYT, IYT, AYT, and MLT pipeline (figure 1).

Selection criteria

Figure 1 summarises the breeding and selection (B & S) scheme and the selection criteria at each trial stage over season and location employed by the ISAR bean research programme (both bush and climbers). They range from resistance and tolerance to major diseases and pests (D & P), low soil nutrients, plant vigour, seed market class, maturity duration, yield potential, and finally, general adaptability in multiple environments and acceptability to farmers and other end users. It generally takes seven to over 10 years to release a new variety.

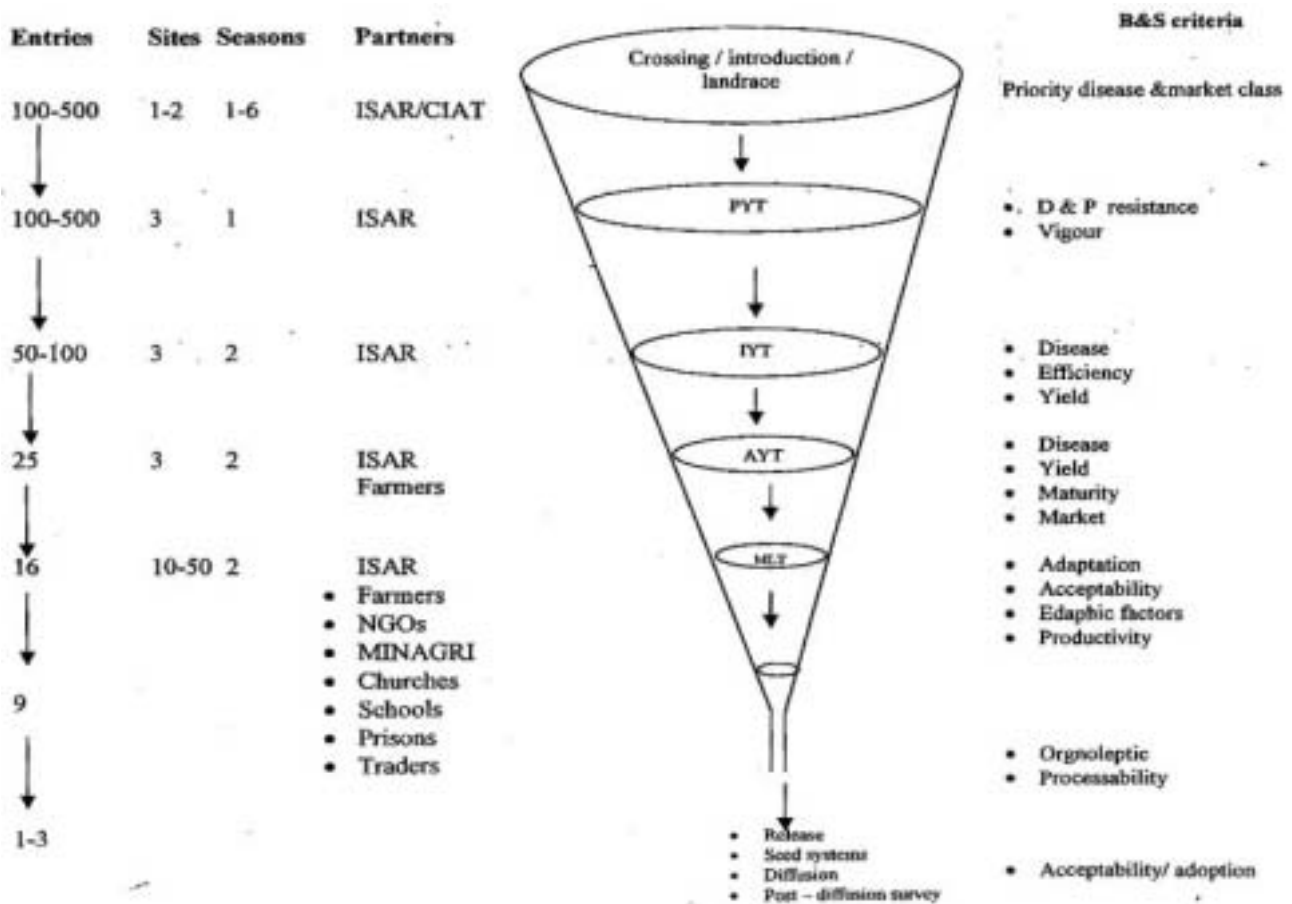


Figure 1. ISAR generalised breeding and selection scheme

Release and seed system

Once a new variety is acceptable, small quantities (about 5 kg) of breeder seed is multiplied on-station by the bean programme and ISAR Seed Unit. It is then forwarded to the National Seed Service Unit of the Ministry of Agriculture for further production of basic and certified seed. The seed is sold to farmers and farmers' co-operatives (CBOs) but mostly to agricultural promotion government organisations (GOs), non-government organisations (NGOs), and international agencies (e.g., FAO) which distribute the seed to farmers.

Informal seed channels

However, farmers also obtain seed by informal means. They increase and plant seed of their 'own released' varieties from multilocational trials or those selected under participatory breeding. They also usually maintain stock of the initial seed (which they share) obtained through the formal systems.

ISAR-farmer diffusion

More recently, the ISAR bean programme and Seed Units through technology-transfer promotion activities has multiplied and distributed tonnes of breeder seed to farmers, CBOs, and NGOs for planting or further multiplication.

Participatory variety selection

Along the formal breeding and selection chain, participatory approaches are used. Farmers, mostly women bean experts, are invited to research stations and are exposed to large selections of germplasm, at the IYT and AYT stages, where they select varieties in terms of agronomic, morphological, and market characteristics. Those that are considered adaptable to their local environments are further experimented with by the farmers under their actual growing conditions and systems before they are adopted. This has been found to enhance informal variety diffusion and adoption as well as lowering research time and the costs of developing bean varieties. It also broadens the genetic base of bean germplasm on-farm (Sperling, 1990).

Partnerships

Figure 1 shows some of the key ISAR partners involved in the research and dissemination processes. CIAT (and the bean networks RESAPAC and ECABREN) were important sources of exotic climbing bean germplasm and its testing. The GOs, NGOs, and CBOs have been helpful disseminators of improved varieties (Musoni and Buruchara, 1999).

RESEARCH ACHIEVEMENTS

Improved varieties

Two decades of intensive research on climbing beans have resulted in the release of a number of improved climbing bean varieties. Among the first to be released in 1985 were Umubano (G2333), Vuninkingi (G685), Ngwinurare (59/1-2), Flora de Mayo and Puebla, and Gisenyi 2 bis. They had a high yield potential of 3.0 to 5.0 t/ha (200% to 300% higher) and better tolerance to disease than the improved bush types (Nyabyenda, 1991). These attributes made them more popular and encouraged farmers to replace the bush types and local climbers with the improved climbers, especially after the problems with root rots since the late 1980s.

New varieties

Breeding and selection continued after the brief interruption of the war and genocide of 1994, resulting in new releases of improved climbing cultivars such as CAB19, G2331, RWV 524, Decelaya, CAB 2, CAB 28, RWV 167, RWV 377, LAS 405, NG 244- 4, and RWV 296, among others (Musoni, various years). Table 3 shows the most important climbing bean cultivars that have been released and disseminated to farmers during the last two decades and their main features.

Table 3. List of Climbing Bean Varieties Released by ISAR (1985–2001)

Variety	Farmers' name	Origin	Seed type colour		Maturity (D)*		Yield (T/Ha)	Market potential
			Size	Colour	MidAlt.	HighAlt.		
G2333	Umubano	CIAT	S	Red	90	112	4.0 - 4.5	Local consumption
G685	Vuninkingi	CIAT	S	Light red	99	118	4.0 - 4.5	Local consumption
Flor de Mayo	Flora	CIAT	M	Pink	94	118	3.5 - 4.0	Local consumption
G858	Muhondo 6	CIAT	M	Yellow	94	118	4.0 - 5.0	Urban & regional
Gisenyi bis	Gisenyi	ISAR	L	Zebra	88	111	2.0 - 3.0	Urban & regional
Urunyumba 3	Urunyumba	ISAR	L	Light red	85	112	2.0 - 3.0	Local consumption
59/1-2	Ngwinurare	ISAR	L	Red	89	*	3.0 - 3.5	Urban & regional
NG 224-4	Ikinyamanza	ISAR	L	Zebra	84	*	4.0 - 4.5	Urban & regional
RWV 296	Amakwamire	ISAR	L	Zebra	84	*	3.5 - 4.0	Urban & regional
RWV 167	Ndamirabashonji	ISAR	S	Red	90	*	4.0 - 4.5	Local consumption
CAB 19	Akezakarigura	CIAT	S	White	84	*	4.0 - 4.5	International export
CAB 2	Nyiramata	CIAT	M	White	*	130	4.5 - 4.5	International export
Decelaya	Decelaya	CIAT	L	Red	80	*	3.5 - 4.0	Urban & regional
CAB 28	Karera	CIAT	S	White	85	*	3.5 - 4.0	International export
LAS 405	Bineza	CIAT	L	Red	*	120	4.0 - 4.5	Urban & regional
RWV 377	Munezero	ISAR	L	Red	*	118	3.5 - 4.0	Urban & regional
G2331	Mamesa	CIAT	M	Yellow	*	120	3.5 - 4.5	Urban & regional
RWV 524	Ayinyana	ISAR	M	Calima	*	120	3.5 - 4.0	Urban & regional

Note: All beans are type IVA.

* Maturity in days not applicable as varieties were selected for mid or high altitude only, following decentralised variety selection in the 1990s.

Staking

Research into appropriate staking options for climbing beans recommends the planting of leguminous agroforestry trees like *Calliandra*, *Leucaena*, *Alinus*, and *Sesbania* species. These take six months to one year to produce the first stakes. *Calliandra* and *Leucaena* species regenerate and multiply faster after cutting. Stakes are re-used for up to six bean seasons. Optimal length of the stake is 2 m (1.5 m is okay). This is enough to support four bean plants at the rate of about 50,000 stakes per hectare (500 per are). With appropriate farmer skills, one stake can support six to eight plants, reducing the rate to 250–375 stakes per are.

EXPANSION, ADOPTION, AND IMPACT

Expansion

During the last quarter of the millennium, the use of climbing beans spread from native pockets in the highlands of the Great Lakes Region of Africa in northern Rwanda, Burundi, eastern D.R. Congo, western Kenya, southern and eastern Uganda, and the Mt Kilimanjaro zone in Tanzania and has covered larger areas of the same high-potential regions. More recently, the use of climbing beans has extended to nontraditional wet mid-altitude zones of central and southern Rwanda. About 33,000 hectares of climbing beans (17% of the area under beans) are planted in Rwanda annually (Sperling et al., 1992). The acreage in sub-Saharan Africa is estimated at 100,000 hectares. Rwanda has been the main source of climbing bean germplasm in the region.

Adoption and impact

Assessment studies in Rwanda (Sperling et al., 1992; Sperling, 1995) show the overall rate of adoption of climbing beans increasing from under 5% (early 1980s) to 42% (1992) and 47% (1995). Adoption ranged between 47% and 90% in six of 10 provinces that have conducive environments, or in those that were deliberately targeted by research and development projects (CIAT, 1992). Improved technologies for climbing beans were adopted equally by wealthy and poor farmers, irrespective of gender. As a result of increased bean productivity, farmers were earning extra income equivalent to US\$12.5 million annually (Sperling et al., 1992).

WHY THE SUCCESS STORY?

Several interrelated factors have contributed to the dramatic spread of improved bean technologies in Rwanda. Most notable is their high productivity, tolerance to diseases, and the actual availability of improved varieties through research and extension.

Tolerance to diseases

Climbing beans have proved to be more resistant and tolerant to major fungal diseases, particularly root rots, anthracnose, and angular leaf spot, than the more traditionally grown bush types. The sharp rise in the adoption of climbing beans in Rwanda in the 1980s and in western Kenya and southwestern Uganda in the 1990s was a direct consequence of the root-rot epidemics in those countries, which severely attacked and damaged local and improved bush germplasm in farmers' fields (Sperling, 2001; David et al., 2002).

Productivity and land economy

The equivalent land ratio for climbing compared to bush beans is 1:3. This means that farmers are able to produce the same quantity of beans on only 30% of the land otherwise needed for bush beans. This minimises costs of production in such things as fertilisers and labour. It also saves land and inputs to grow or invest in other crops, especially those that provide complementary starchy or vegetable diets. With larger plots, extra bean yields are marketed to obtain cash that is used to buy other foods or home requirements. In this way, growing climbing beans is said to *expand* arable land (Voss and Graf, 1991).

Quick releases and strategic dissemination

ISAR has consistently selected, released, and promoted new varieties of climbing beans since their introduction to Rwanda in the early 1980s. Linkages have been established and maintained with other research institutes (CIAT, RESAPAAC, and later, ECABREN) and multiple partners under government and NGO extension and development projects, as well as farmers throughout the country. Farmers were given a wider choice and have been involved in selecting new varieties through participatory research. Large quantities of seed of new

varieties have been produced both formally and informally and strategically distributed to farmers (with promotional fliers or brochures) in small packets, according to need and affordability.

Staking and protection of the environment

Staking is an oft-sited constraint, but it is not a challenge to poor, subsistence farmers, who usually have a surplus of family labour (Pachico, 1984; Voss and Graf, 1991). They also save some labour by planting smaller plots of climbers. The farmers who plant the fast-growing, regenerating leguminous and nitrogen-fixing trees like *Calliandra* spp., *Sesbania* spp., and *Leucaena* spp. obtain stakes easily. These trees are usually planted on farm terraces and borders or hilltops. Besides providing wood for stakes, they protect the soil against erosion. Their residues are applied as green manure to improve soil fertility or used to supplement animal feeds. Old stakes are used to make fires for cooking, thus alleviating energy shortages.

The thick canopy of climbing beans provides ground cover most of the year. This also reduces wind and rain erosion. The large biomass of residues is a potential source of animal feed and compost manure. Both the agroforestry trees and climbing beans play an important role in recycling water and soil nutrients.

Policy

Beans are regarded as number one among the food crops in Rwanda in terms of nutritional value. They come next to cereals (maize and rice) in terms of research priority (cereals are relatively new in Rwanda). Most government and other agriculture-based organisations and projects work on beans as a policy.

CONCLUSION

As arable land continues to diminish with population rise, intensification of agriculture in Rwanda and Africa is inevitable. The use of high-value and highly productive climbing bean cultivars will contribute towards reducing associated food insecurity and malnutrition. Farmers will do what it takes to realise the productivity potential of climbing beans. They have to overcome challenges, including supplying staking materials through the use of multipurpose leguminous agroforestry species and other innovations. Multiple partnerships are essential for farmers to realise these goals. But as Sperling (1996) observes in her national survey report, 'Impact of War on Agricultural Production in Rwanda': *Improved climbing bean use [in Rwanda] is on the rise. . . . It will be for researchers to offer a greater diversity of the climbers [to farmers].* This is the challenge that ISAR faces, especially the development of more varieties with seedtypes (such as the red mottled) that have wider market preference in the region.

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COMMON BEAN IMPROVEMENT PROGRAMME IN SUDAN

Elsadig Suliman Mohamed

ABSTRACT

The common bean is the second most important food legume (after faba beans) in the Sudan. It is normally cultivated under residual soil moisture in basin and islands after recession of the flood. Appreciable areas are also grown under irrigation. The limiting factors for common bean production in Sudan are the lack of improved seeds, poor cultural practices, and pests and diseases. The overall objective of the breeding programme for common beans in Sudan has been to develop genotypes with high, stable yields and good-quality seed, with secondary objectives to breed for resistance or tolerance to stress conditions (especially diseases, insect pests, and limited moisture). This paper reports on four cultivars released in the previous 10 years. All cultural practices have been determined. Farmer's field schools have been established and IPM demonstration plots have been set up to demonstrate IPM practices versus farmers' methods of insect control. An extension programme has also been launched in collaboration with the staff of the Regional Ministry of Agriculture in the Nile State to verify and demonstrate improved technologies.

RÉSUMÉ

Au Soudan, le haricot commun est la deuxième légumineuse par ordre d'importance après la fève. Sa culture se pratique normalement sur les sols humides résiduels des bassins et des îles après la décrue des eaux. D'importantes zones irriguées sont également cultivées. Les obstacles à la production du haricot commun sont le manque de semences améliorées, l'absence de bonnes pratiques culturales ainsi que les ravageurs et les maladies. Le programme de sélection du haricot commun au Soudan avait pour but de développer des génotypes ayant des rendements élevés et stables et des semences de bonne qualité, avec pour objectifs spécifiques une résistance ou une tolérance aux diverses contraintes (en particulier les maladies, les insectes ravageurs et l'humidité insuffisante). Ce document fait état de quatre cultivars introduits au cours de ces dix dernières années. Toutes les pratiques de culture ont été définies. Des stages sur le terrain destinés aux agriculteurs ont été mis en place ainsi que des parcelles de démonstration de la lutte intégrée contre les ravageurs afin de montrer l'avantage de celle-ci par rapport aux pratiques insecticides des cultivateurs. Un programme de vulgarisation a également été lancé en collaboration avec les membres du personnel du Ministère régional de l'État du Nil afin de faire la démonstration des techniques améliorées.

INTRODUCTION

The common bean is the second most important food legume (after faba bean) in the Sudan, where it is normally cultivated under residual soil moisture in basins and islands after recession of the flood. In addition, appreciable areas are also grown to common bean under irrigation. About 90% of the crop is produced in the northern part of Sudan. In recent years, common beans have been grown on more than 15,000 ha, with yields varying from 1.0 t/ha to 1.8 t/ha—much less than the yield potential of this crop. Acreage planted to common beans is chiefly governed by the amount of the flood, market price, and competition with other crops. However, areas, production, and yield of common beans have all been increasing trend the last five years.

The following constraints contribute to the low productivity of common beans:

1. lack of high-yielding cultivars
2. poor cultural practices
3. insect pests and diseases
4. weeds
5. inadequate access to credit and marketing arrangements

OBJECTIVES OF THE COMMON BEAN PROGRAMME

The main role of this programme is to improve crop productivity and quality through plant breeding, plant protection, and crop husbandry. The main objectives include the following:

1. Development of a cost-effective production technology that is also tolerant of natural and biological stresses, with the following activities:
 - testing genotypes for high and stable seed yields and good-quality seed
 - screening genotypes for early maturity and tolerance to abiotic stresses, especially limited moisture, sub-optimal irrigation, and high temperatures
 - screening genotypes for resistance or tolerance to biotic stresses, namely diseases and insect pests
 - developing the best management practices to boost yield
 - developing simple, safe, and affordable pest-management strategies
 - producing breeder and foundation seeds
 - collecting, crossing, and maintaining genetic resources
2. Verification and demonstration of the improved production packages to disseminate the recommended technology
3. Study of the adoption and impact of demonstrated technology to trace farmers' acceptance of the technology and identify factors that limit or encourage farmers' adoption

HIGHLIGHTS OF ACHIEVEMENTS

In addition to R/O/2/1, three cultivars (Giza 3, Bassabeer, and Sarraj) have been released in the past five years as higher yielding, short maturing, more stable, and/or of better seed quality. More than 60 genotypes of common beans have been evaluated in preliminary, advanced, and verification yield trials for adaptability, high yield, and yield stability and quality at different locations in Sudan. The genotypes included in these trials originated from both local selections and introduced material. The genotypes Berber L., Salwa white, and ABA 61 proved superior in the verification yield trial and gave the highest seed yield over three seasons. The average seed yield of these genotypes ranged from 1.8 t/ha to 2.0 t/ha and exceeded the best check, Giza 3, by up to 25% (table 1). These genotypes will be submitted to the Variety Release Committee for recommendation.

Table 1. Average Seed Yield and 100-Seed Weight of Three Common Bean Genotypes Compared to Two Checks over Four Years

Cultivars	Yield (t/ha)	100-Seed weight (g)
Berber large	2.24	28.8
ABA61	1.98	33.4
Salawa white	1.87	22.0
Giza 3 (check)	1.86	25.1
R/O/2/1(check)	1.85	22.2

In the preliminary and advanced yield trials, on the other hand, a number of genotypes have been identified as superior to the checks. A crossing programme was started at Hudeiba Research Station in 1999/2000. More than 100 single crosses were made among parents of interest, but only 21 gave seeds. The F₁ seeds were crossed to the third parents (F₁ x P), but only eight succeeded. The selection criteria are early maturity, high number of pods per plant, and larger seed size. All selections and crosses are maintained for further selection and evaluation.

Twenty of the most promising common bean genotypes were screened for resistance to charcoal rot in a naturally infested area at Hudeiba Research Farm, and symptoms were observed on 16. Plants with typical charcoal symptoms ranged between 5% and 42%. Samples of plants showing symptoms of root and/or stem

rot from the released common bean variety R/O/2/1 and a local variety were used for isolation and identification of the causal pathogens. Based on the results of the isolations, *Macrophomina phaseolina* was the most predominant fungus (50%), followed by *Fusarium oxysporum* (28%), *Helminthosporium sp* (2%), and *Fusarium solani* (10%).

The four released cultivars were tested under natural field conditions to study the incidence of virus diseases. Variety R/O/2/1 scored the lowest disease incidence (1%), whereas variety Bassabeer scored the highest disease incidence (15%).

A number of field experiments were conducted during the 1999–2001 seasons at Hudeiba Research Station to evaluate the agronomic performance of some common bean cultivars (table 2):

1. The sowing date was found to have a significant effect on seed yield and most of the yield attributes measured, with October sowing giving higher yields than November sowing. There were no significant differences between cultivars in their response to sowing dates.
2. The sowing method and intra-row spacing was also investigated, revealing that sowing common beans on both sides of the ridge gave higher seed yields than sowing only on the top of the ridge.
3. Nitrogenous (N) fertiliser increased grain yield and yield components of common bean. In contrast, phosphorus (P) had no significant effect on common bean productivity.

Table 2. Effect of Agronomic Variables on Yields of Common Beans

Treatment	Yield (t/ha)	
	1999/2000	2000/01
Sowing date		
13 October	1.42	2.9
27 October	1.85	2.74
10 November	1.5	2.15
24 November	1.4	1.94
S.E. \pm	0.092	0.11
Method of sowing:		
On the top of the ridge	1.69	2.28
On both sides of the ridge	1.91	2.79
S.E. \pm	0.07	N.S.
Intra-plant spacing:		
10 cm	1.75	2.52
15 cm	1.83	2.52
20 cm	1.83	2.56
S.E. \pm	N.S.	N.S.
Fertiliser		
0.0 N	1.92	2.51
0.5 N	2.02	2.63
1.0 N	2.10	2.73
S. E. \pm	0.03	0.04

The effect of irrigation intervals (every 12 or 24 days) and the fungicide Vitavax (as IDM) on the incidence of charcoal rot and bean root rot on R/O/2/1 and Giza 3 has also been evaluated at Hudeiba Research Station.

IPM technology has been developed and has been demonstrated to farmers.

A survey was carried out in five major bean-producing areas, showing that insect damage on common beans was significant and aggravated by an increase in temperature. The most important insects are *Bemisia tabaci*, *Helicoverpa armigera*, *Agrotis ipsilon*, *Spodoptera exigua*, and *Aphis craccivora*. The most dominant natural enemies are *Chrysoperla carnea* and the syrphid fly. Most of the farmers are aware of manipulation of sowing date as a measure of pest control, but they are ignorant of pest status in their fields and do not know

natural enemies and the rationale of pesticide use. Therefore, IPM technology has been developed with the following strategies:

1. intercropping beans with coriander
2. applying mild and softer insecticides
3. applying Neem-seed water extracts

Farmer's field schools have been established in bean-producing areas and IPM demonstration plots were implemented to demonstrate IPM practices versus farmers' methods of insect control.

The programme is working towards improving the production of common beans by means of a stepwise research approach from on-station to on-farm levels. An improved package has been developed by the programme and recommended for wider on-farm trials for verification and demonstration. A package of five factors has been demonstrated in bean-producing areas in northern Sudan. It consists of

1. an improved cultivar (R/O/2/1)
2. early sowing (last week of October to first week of November)
3. a seeding rate of 60 kg/ha
4. fertiliser, as 43 kg N/ha
5. pest control

Results of on-farm trials indicated the feasibility of the use of an improved package of irrigated common beans in Lower Atbara. In the plots using the improved package, grain yield varied from 1.65 t/ha to 2.5 t/ha, with an overall mean yield of 2.0 t/ha. In neighbouring plots, grain yield ranged from 0.62 t/ha to 1.86 t/ha, with an average yield of 0.99 t/ha. Partial budgeting and marginal analysis indicated that the use of the improved package is a profitable alternative for farmers (table 3).

Table 3. Grain Yield, Costs, and Returns (LS/ha) and Marginal Rate of Return of the Irrigated Common Bean Alternative Production Package in Lower Atbara, 1995/96

Treatments	Average yield (t/ha)	Variable costs	Gross returns	Net returns	MRR (%)
Traditional	0.99	161976	308,947	146,971	
Improved	2.00	217824	626,994	409,170	569

An extension programme has been launched in collaboration with the Regional Ministry of Agriculture in the Nile State to verify and demonstrate the generated improved technology. The programme includes the following:

- pilot/demonstration plots
- farmers' field days at Hudeiba, Shendi, and Berber
- production of extension leaflets
- mass media (radio and TV programmes)
- field visits
- travelling workshops

FUTURE PROSPECTS

- A market-oriented approach with good-quality produce must be included among the top priorities (high and stable yield) of the breeding programme.
- The existing genetic base is very narrow and its enrichment is essential in screening for both biotic and abiotic stresses (water stress, heat stress, and salinity).

- Improved seed multiplication and distribution should be looked at seriously in order to improve farmers' yields.
- Developing relevant cultural practices for the common bean under residual soil moisture is strongly needed.
- The IPDM research programme should be strengthened.
- Farmer participation in developing the technology should be emphasised (farmers' participatory approach).
- On-farm testing and demonstrations are needed to promote the generated technology.
- Linkages between research and extension should be strengthened.
- Socio-economic studies need to be carried out.

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AUGMENTATION DE LA DIVERSITÉ GÉNÉTIQUE DU HARICOT COMMUN (*PHASEOLUS VULGARIS* L.) EN MILIEU DU PAYSAN : ÉTUDE D'UN CAS DE SÉLECTION PARTICIPATIVE AU KIVU MONTAGNEUX (RÉPUBLIQUE DÉMOCRATIQUE DU CONGO)

Nkonko Mbikayi et Philippe Bakunzi

RÉSUMÉ

Le Programme national des plantes légumineuses de l'INERA-Mulungu a mené une étude de trois ans (1993–1996) sur la participation des paysans aux processus de sélection et de transfert de nouvelles variétés, approche importante pour assurer la sauvegarde de la diversité génétique du haricot commun dans le Nord et le Sud-Kivu. Ces deux régions de la République Démocratique du Congo ont été subdivisées en six sites d'expérimentation où la méthode de la sélection variétale fut appliquée de concert avec les paysans et où l'on a pu étudier le circuit de diffusion informel utilisé par les cultivateurs pour transmettre de nouvelles variétés de haricot. La méthodologie de sélection participative développée avec l'assistance du Centre international d'agriculture tropicale (CIAT) a ainsi été expérimentée pour voir si elle peut favoriser les chances d'adoption de nouvelles variétés de haricot dans le milieu du paysan. La création de sites de sélection décentralisés pouvant servir de sources d'approvisionnement pour de grandes zones de production est un des résultats de ce projet de recherche, qui de plus a donné une impulsion au transfert par les paysans mêmes de variétés nouvellement co-sélectionnées et adoptées.

ABSTRACT

From 1993 to 1996 INERA researchers (of the national beans and legumes program based in Mulungu) carried out a project involving local farmers in plant-breeding and dissemination activities, as a means to protecting the genetic diversity of the common bean in two regions of the Democratic Republic of Congo known as North and South Kivu. Having subdivided these regions into six experimental areas, they invited farmers to participate in variety-breeding activities and they studied the existing informal distribution channels through which farmers shared new bean varieties. This allowed them to test the participatory plant-breeding methodologies developed with CIAT assistance to see whether they can improve the rate of adoption of new bean varieties by farmers. This research project has contributed to the establishment of decentralised plant-breeding stations to supply breeder seed to large production zones and it stimulated the transfer of jointly bred and newly adopted varieties among farmers.

INTRODUCTION

Le succès et la stabilité d'une culture dans un milieu donné se mesurent par sa diversité génétique, signe de son adaptabilité et de son acceptabilité aux yeux des utilisateurs. Cette diversité doit être maintenue en principe par l'introduction continuelle de nouvelles technologies culturelles.

Un cas d'espèce : dans la région des Grands Lacs d'Afrique centrale, dont fait partie la République Démocratique du Congo (RDC), le haricot commun (*Phaseolus vulgaris* L.) est une des légumineuses à graines les plus importantes en termes de production et de consommation (Wortmann and Allen 1994) : il y représente plus de 45 % des protéines de la ration alimentaire des familles les plus démunies. La production de haricots est la plus élevée au Kivu montagneux, partie de la RDC caractérisée par plusieurs microclimats et variations édaphiques remarquables, facteurs qui influent sur la productivité de cette plante. Au sein des systèmes de production traditionnels et complexes, la production du haricot est transmise de génération en génération et les cultivateurs sont pour la plupart des femmes.

L'introduction d'une nouvelle variété de haricot par la recherche demande la participation de ces cultivateurs : en effet, si les utilisateurs sont impliqués dans le choix d'une variété nouvelle, celle-ci a de bien

meilleures chances d'être adoptée dans leur milieu car les utilisateurs ont parfois des critères de sélection que la recherche ignore ou néglige. Aux yeux des cultivateurs du Kivu, adaptabilité et acceptabilité sont des critères de grande importance.

Le projet de recherche présenté ici avait pour but et objectifs principaux

- d'étudier l'augmentation des chances d'adoption de nouvelles variétés par l'application de la sélection participative ;
- de promouvoir la création de groupes de sélection décentralisée de nouvelles variétés de haricot ;
- d'examiner les mécanismes informels de transfert d'une nouvelle technologie—en l'occurrence, d'une nouvelle variété.

MATÉRIEL ET MÉTHODES

Généralités

L'étude a débuté au mois de mars 1993, avec l'installation de six pépinières de sélection participative au Nord et au Sud-Kivu, suite à la tenue d'un séminaire pour former les techniciens des sites choisis comme collaborateurs au projet.

Au Nord-Kivu, deux pépinières ont été installées et évaluées à Rugari (Goma) et à Kibututu (Rutshuru), en collaboration avec le Service National de Vulgarisation (SNV) et le Centre Baptiste de Kibututu/CDRU.

Le Sud Kivu a vu l'installation et l'évaluation de quatre pépinières de sélection participative, en collaboration avec le Projet Kabare : les pépinières de Kashusha et de Konge en zone de Kabare, et celles de Burhale et de Mushinga dans la zone de Walungu.

Après avoir choisi, de concert avec les paysans, le terrain d'expérimentation, l'équipe a semé quinze variétés de haricot dans chaque site, variétés de haricot de type nain, semi-volubile et volubile que les paysans locaux avaient présélectionnées au cours d'une journée champêtre. Les dimensions des parcelles étaient, pour les variétés de type volubile, de 3 m de longueur sur 1 m de largeur, et pour les variétés de types nain ou semi-volubile, de 3 m sur 80 cm. Les semis ont été effectués selon la pratique des paysans des lieux : semis en lignes (deux lignes par parcelle) ou en vrac (60 graines par parcelle). Un sentier de 1 m séparait les répétitions et les deux essais. Les variétés volubiles ont été tuteurées après l'apparition des vrilles, à raison de 5 plants de haricot par tuteur, ou selon la pratique du paysan.

L'expérience s'est déroulée selon la méthodologie décrite ci-dessous et un questionnaire fut élaboré pour recueillir les impressions des paysans ayant participé sur le déroulement des activités. L'objectif de cette étude menée en 1993 était de faire participer les paysans dans le choix de nouvelles variétés à diffuser et de tester l'efficacité de la méthodologie de sélection participative par l'augmentation des chances d'adoption de nouvelles variétés.

Méthodologie de la sélection participative

La méthodologie de la sélection participative a consisté en l'exécution des opérations suivantes pendant la période végétative de remplissage des graines (R8) et à la maturité complète (R9) :

1. Délimitation de la parcelle en indiquant le nom de chaque variété sur les piquets ;
2. Placement d'un sachet rempli d'étiquettes portant le nom de la variété d'étiquettes : les paysans retireront ces étiquettes pour indiquer leur choix de variété préférée ;
3. Placement d'un échantillon de graines de la variété à côté du sachet ;
4. Préparation de deux groupes de rubans : rubans roses pour marquer l'acceptation (et donc « l'acceptabilité ») de la variété et rubans noirs pour indiquer le rejet ;
5. Inscription du numéro identificateur de chaque fermier/fermière sur quatre rubans de couleur rose pour pouvoir enregistrer les quatre premières préférences ;
6. Distribution des rubans : chaque fermier/fermière reçoit quatre rubans roses et quatre noirs. (Ce nombre peut varier en fonction du nombre des variétés en expérimentation, le but étant de mettre les cultivateurs en état de faire de bons choix en évitant la confusion dans les esprits.)

7. Explications et instructions : les paysans sont priés d'attacher les rubans sur les piquets, rose pour marquer le choix de la variété préférée et noir pour indiquer le rejet de la variété ;
8. L'activité même : les paysans circulent dans la pépinière pour d'abord choisir les variétés préférées, en attachant des rubans roses et en prenant à chaque fois une étiquette avec le nom de la variété choisie. (Au besoin, distribution de rubans additionnels).
Après la sélection des variétés préférées, les paysans refont le tour du terrain pour placer les rubans noirs sur les piquets des variétés qu'ils n'aiment pas, sans retirer d'étiquettes cette fois-ci ;
9. Enregistrement des variétés choisies en notant les noms sur les étiquettes retirées ;
10. Comptage des étiquettes et des rubans pour contrôle ;
11. Enregistrement des raisons que le paysan donne pour expliquer sa décision de choisir ou rejeter telle ou telle variété expérimentée dans son milieu.
12. Tour de question : le sélectionneur (ou son représentant) invite les paysans à l'interroger sur l'expérience et répond aux questions.
13. Remerciements : le sélectionneur/son représentant remercie les paysans de leur participation.

Les données enregistrées au cours de l'opération et converties en pourcentages permettent de procéder à une analyse fréquentielle et à la comparaison des moyennes obtenues. Cette comparaison a permis de déceler la tendance générale d'adoption ou de rejet des variétés étudiées, entre trois et cinq ans après leur introduction dans le milieu paysan.

Adoption et étude du circuit informel de transfert de technologie

Cette phase de l'étude a commencé en 1996, soit trois ans après l'installation des pépinières de sélection participative dans les sites choisis. Elle avait pour objectifs de voir si les paysans cultivaient toujours les variétés qu'ils avaient sélectionnées trois ans auparavant et aussi s'il y avait eu un transfert de ces semences des paysans bénéficiaires vers d'autres et, le cas échéant, comment ce transfert s'était produit. Pour répondre à ces questions, les chercheurs ont eu recours à la méthode d'échantillonnage : ils ont contacté environ 80 paysans, disponibles au moment de l'enquête.

RÉSULTATS ET DISCUSSION

La sélection participative

La collecte des données a eu lieu à différents moments de la croissance du haricot—pendant la phase du remplissage des gousses (R8) et à la maturité complète de la plante (R9)—pour voir si oui ou non le paysan pouvait changer d'un stade à l'autre. Nous avons pu constater qu'en effet, le choix de la variété variait parfois : par la représentation graphique des préférences enregistrées aux deux stades, les figures 1 et 2 font ressortir la tendance des cultivateurs à réagir différemment aux différents stades du haricot. La figure 1 se rapporte aux haricots de type nain ou semi volubile, et la figure 2 aux haricots de type volubile. Les graphiques sont basés sur les résultats obtenus suite à l'enregistrement du nombre de fois que le choix des paysans favorisait une même variété : les fréquences moyennes ont été converties en pourcentages.

Le choix du paysan repose sur l'ensemble des critères de sélection que le paysan considère avant de se prononcer. Cet ensemble de critères définit les paramètres de l'« acceptabilité » d'une variété donnée. L'acceptabilité d'une variété aux yeux du paysan augmente les chances de la variété d'être adoptée dans le milieu réel.

Les critères que les paysans considéraient en évaluant une variété étaient, de façon générale, le rendement, la production en feuilles « bishogolo » utilisables comme légumes dans l'alimentation humaine, la résistance aux pluies (maladies, insectes), la précocité, la couleur et la grosseur des graines, la ressemblance à une variété locale bien appréciée. Le goût fait partie de l'évaluation, lui aussi, mais bien après.

Comme nous l'avons noté la choix du paysan pouvait varier selon le moment de l'évaluation : les paysans attachaient plus d'importance à certains critères au cours de la végétation, et se concentraient sur d'autres au moment de la maturité complète de la plante.

Le dépouillement statistique a été fait en tenant compte des types de croissance et par stades de croissance.

Haricot nain/semi-volubile (sv)

Au stade de la croissance végétative (R8, remplissage des gousses), les variétés de haricot nain/semi-volubile (sv) ont été sélectionnées avec un taux d'acceptabilité variant entre 0,0 % pour la variété A 74 et 19,7 % pour la variété AND 664. Toutefois, le test de Duncan ne révèle pas de différence significative entre les sept premières variétés (AND 664, AFR 198, AND 665, G 2858, AND 657, A 321, AND 620).

Au stade de la maturité complète (R9), les variétés de haricot ont été choisies avec un taux d'acceptabilité variant entre 0,3 % (variété XAN 68) et 13,0 % (variété PVA 1438). Cependant aucune différence significative n'a été remarquée entre les six variétés qui ont reçu les plus larges cotations, à savoir PVA 1438, RWR 362, ECUADOR 299, AND 664, AFR 198 et AND 665.

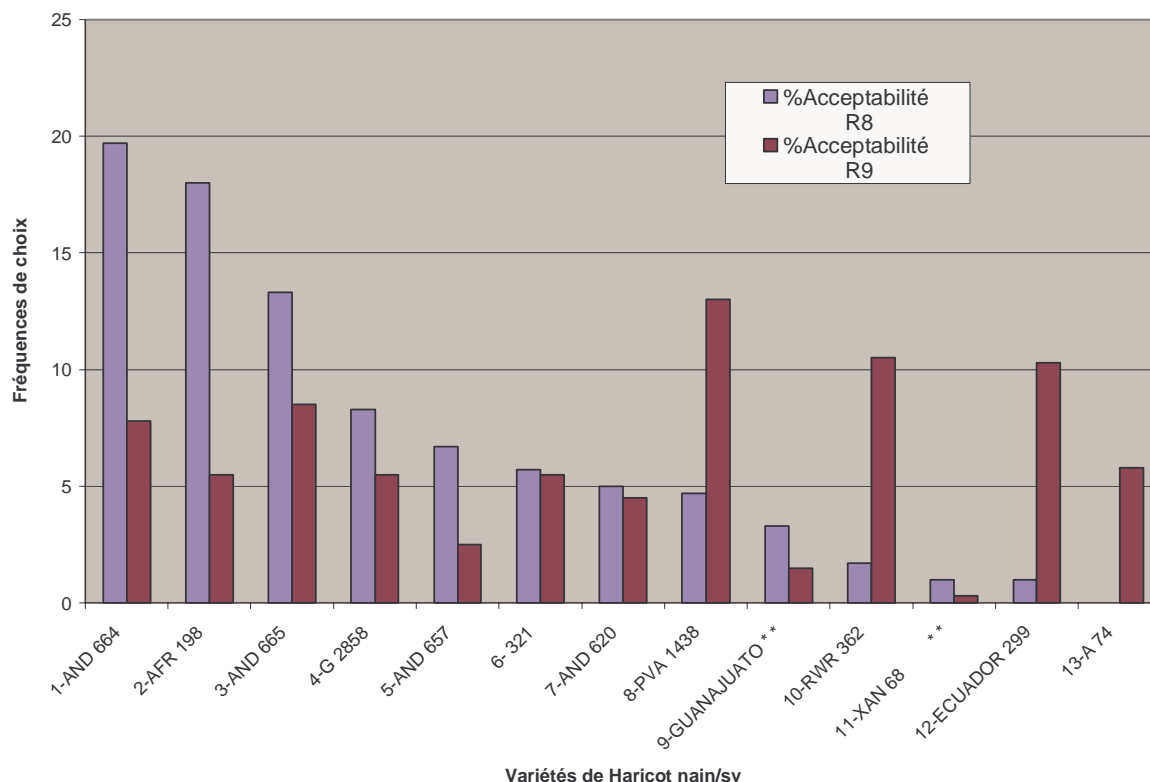


Figure 1. Taux d'acceptabilité des variétés de haricot nain/sv aux stades R8 et R9

Le graphique 1 fait ressortir que pour certaines variétés, l'écart entre les degrés de préférence aux deux stades différents est grand. C'est le cas des variétés suivantes dont les taux d'acceptabilité au stade de la maturité sont bien plus élevés que ceux enregistrés pendant la phase de croissance :

PVA 1438 : 13,0 % (R9) vs 4,7 % (R8) ;

RWR 362 : 10,5 % (R9) vs 1,7 % (R8) ;

ECUADOR 299: 10,3% (R9) vs 1,0 % (R8).

On observe également que les deux variétés GUANAJUATO et XAN68 ont reçu des taux d'acceptabilité très faibles aux deux stades R8 et R9. Pour la variété GUANAJUATO les cotations sont 3,3 % (R8) et 1,5 % (R9) et pour XAN 68 on note 1,0 % (R8) et 0,3 % (R9).

Haricot volubile

Le graphique de la figure 2 permet d'observer la même tendance : la sélection de la variété préférée était différente au stade de croissance par rapport au choix fait au stade de la maturité complète.

Au stade de la croissance (R8), les taux d'acceptabilité vont de 0,0 % (G 11761) à 19,3 % (VCB 81012). Toutefois quatre variétés ont eu des taux d'acceptabilité significativement identiques au seuil de 5 % de probabilité. Il s'agit des variétés ACV 83031, LIB 1, G 59/1-2, ALIYA et VCB 81012.

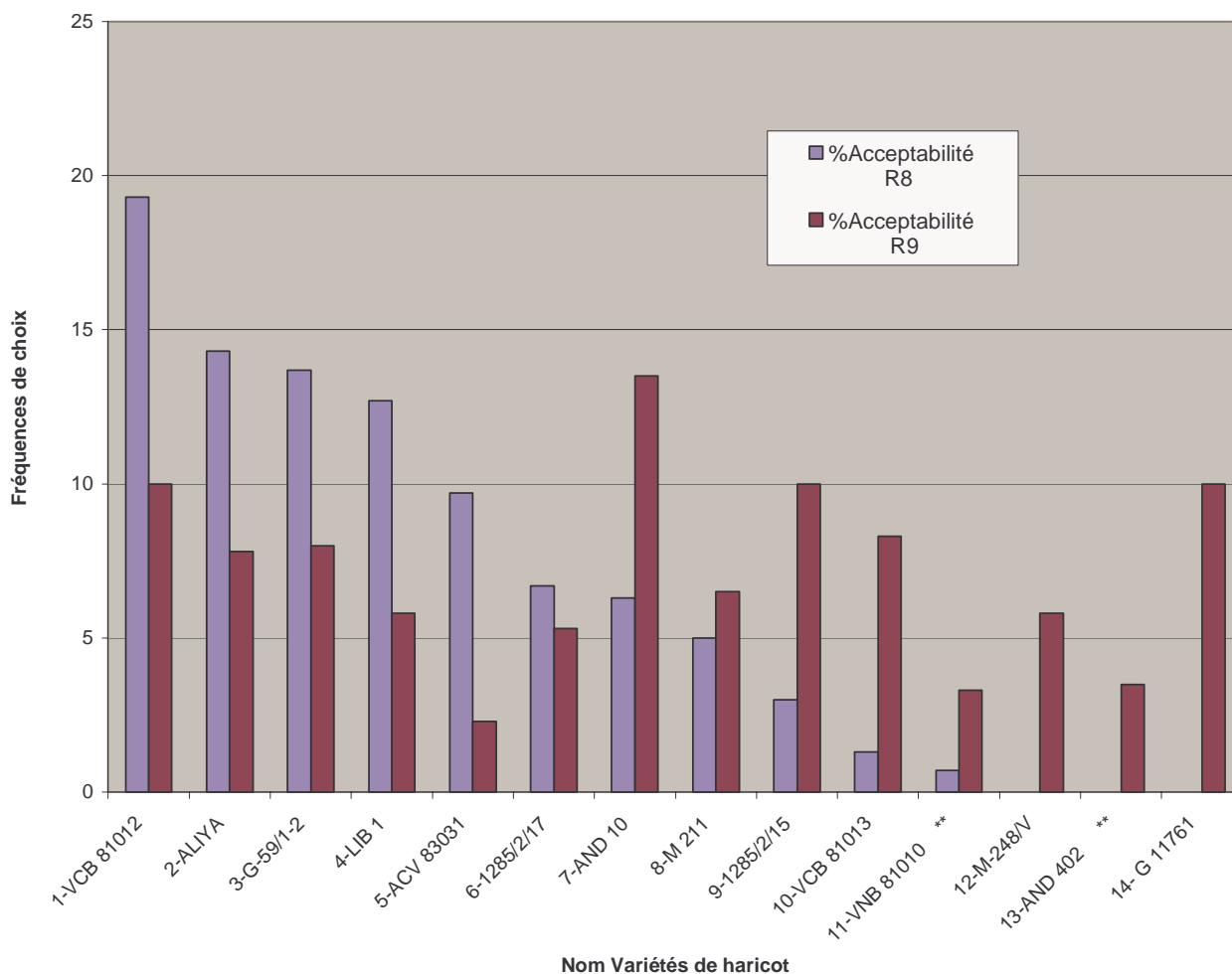


Figure 2. Taux d'acceptabilité des variétés de haricot volubile aux stades R8 et R9

Au stade de la maturité complète (R9), la gamme des taux d'acceptabilité va de 2,3 % (ACV 83031) à 13,5 % (AND 10). Le dépouillement statistique montre que onze variétés ont reçu des taux significativement identiques, à savoir AND 10, VCB 81012, 1285/2/15, G 11761, ALIYA, G 59/1-2, LIB 1, 1285/2/17, M 221, VCB 81013, M 248/V.

Pour deux variétés, l'on note des taux d'acceptabilité faibles aux deux stades. Pour VNB 81010 ces taux étaient de 0,7 % (R8) et 3,3 % (R9), et la variété AND 402 a reçu des cotations de 0,0 % (R8) et 3,5 % (R9).

Différents critères ont donc influencé le choix exprimé par les paysans aux différents stades R8 et R9. Ainsi, au stade R8, nous remarquons l'importance que revêtent les critères « production de bonnes feuilles bishogolo » et « vigueur », tandis qu'au stade R9, les critères qui semblaient compter le plus étaient « précocité » et « grosseur et couleur des graines ». Le dépouillement statistique utilisant le test de Duncan a permis d'examiner les tendances exprimées par le taux d'acceptabilité et l'on distingue de nettes préférences pour certaines des variétés expérimentées.

Adoption et étude du circuit informel de transfert de technologies

Trois ans après l'installation des pépinières de sélection participative en milieu paysan, l'équipe est retournée sur le terrain pour y constater que certaines des variétés que les paysans avaient choisies au moment de la sélection participative existaient toujours en tant que cultures, tandis que d'autres avaient disparu. Les résultats de nos observations sont présentés dans les tableaux 1 et 2.

Tableau 1. Variétés volubiles retrouvées chez les agriculteurs (données converties en pourcentage)

Sites	VCB 81012	M 211	G2333	LIB 1	G 59/1-2	ACV 83031	1285/2/17	G2331	AND10	VCB 81013	1285/2/15
Rugari	3,9	—	3,9	—	0,6	—	—	—	—	—	—
Kagara	3,9	—	2,6	2,6	1,3	1,9	0,6	—	1,3	—	—
Mushinga	14,0	1,9	14,0	1,9	—	—	2,6	—	5,8	2,6	1,3
Burhale	2,6	1,3	8,4	—	0,6	—	—	0,1	5,2	7,7	0,6
Kayanja	2,6	0,6	1,9	—	—	0,1	—	0,6	0,6	—	—
Ndundazi	—	—	—	—	—	—	—	—	—	—	—
TOTAL	27,0	3,9	31,0	4,5	2,6	2,0	3,2	0,7	13,0	10,0	2,0

Tableau 2. Variétés nain/sv retrouvées chez les agriculteurs (données converties en pourcentage)

Site	AFR 198	AND 620	AND 664	G 2858	AND 665	AND 303	AND 657	A 321	Kirundo	RWR 362	Guanajuato	A 285	Nakaja	Ecuador 299	PVA 1438
Kibututu	—	4,2	1,7	3,4	3,4	1,7	0,8	—	—	—	—	—	—	—	—
Rugari	—	—	—	0,8	—	—	—	—	—	—	—	—	—	—	—
Mushinga	—	—	—	—	—	—	—	—	5,6	3,4	5,1	5,1	5,1	1,7	0,8
Burhale	2,5	7,6	5,1	0,8	5,9	—	5,1	5,1	—	11,0	5,1	—	—	2,5	2,5
Kayanja	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Ndundanzi	—	—	—	—	—	—	—	—	—	1,7	—	—	—	—	—
TOTAL	2,5	11,9	6,8	5,1	9,3	1,7	5,9	5,1	5,9	16,1	10,2	5,1	5,1	4,2	3,4

En examinant les fréquences (exprimées en pourcentages) de l'observation de variétés en culture chez les paysans, nous sommes arrivés au classement par ordre d'importance suivant :

Haricot nain/sv			Haricot volubile		
Classement	Variété	Fréquence (%)	Classement	Variété	Fréquence (%)
1,	RWR 362	16,1	1,	Aliya	31,8
2,	AND 620	11,9	2,	VCB 81012	27,0
3,	Guanajuato	10,2	3,	AND 10	13,0
4,	AND 665	9,3	4,	VCB 81013	10,0
5,	AND 664	6,8	5,	LIB 1	4,5
6,	Kirundo	5,9	6,	M 211	3,9
7,	AND 657	5,9	7,	1285/2/17	3,2
8,	G 2858	5,1	8,	G 59/1-2	2,6
9,	A 321	5,1	9,	ACV 83031	2,0
10,	A 285	5,1	10,	1285/2/15	2,0
11,	Nakaja	5,1	11,	G 2331	0,7
12,	Ecuador 299	4,2			
13,	PVA 1438	3,4			
14,	AFR 198	2,5			
15,	AND 303	1,7			

Comme nous l'avons signalé plus haut, certaines variétés avaient disparues : nombre d'entre elles avaient été abandonnées progressivement. Nous avons enregistré les raisons citées par les cultivateurs comme motifs de l'abandon et dressé la liste suivante pour l'un et l'autre type de croissance :

Haricot volubile		Haricot nain/sv	
Variété	Motifs de l'abandon	Variété	Motifs de l'abandon
G 59/1-2	Risque d'une diminution de la production suite à l'insuffisance des pluies		À Rugari les variétés naines avaient été semées sous culture de sorgho et la forte densité a entraîné la perte de ces variétés.
AND 10	Destruction facile par des pluies trop abondantes	AND 303	Diminution de la production en réponse à des ventes à prix réduit
LIB 1	Destruction rapide par les charançons	AND 657	Diminution de la production par manque de résistance aux pluies trop fortes
G 2331	Téguments très durs	Guanajuato	Manque d'appréciation de couleur noire de la graine (même si la variété produisait bien dans les milieux)
12/2/17	Déhiscence rapide : « les gousses s'ouvrent avant la récolte. »	AFR 198	Diminution de la productivité
Certains abandons étaient dus au manque de tuteurs comme supports de haricot volubile.		RWR 362	Découragement par les voisins
		Ecuador 299	Récoltes abîmées par les grêles
		A 74	Floraison tardive (N,B : similitude des variétés A74 et A285, difficiles à distinguer)

Le tableau 3 concerne la diffusion des variétés par le transfert. Sur les 76 questionnés, 60 agriculteurs (soit 79 %) ont cédé leurs variétés, les partageant avec d'autres de la façon suivante : 54 sur 76 (71 %) ont donné des variétés à des voisins ; 35 sur 76 (46 %) ont fait don de variétés à des membres de leur famille et enfin, 31 ont transmis des variétés à d'autres personnes encore (40,6 %).

Tableau 3. Diffusion des variétés dans les sept milieux enquêtés

Site	Personnes interrogées	Ont cédé leurs variétés	Nombre de bénéficiaires	Qui sont les bénéficiaires ?			Mode de cession des semences			
				Membre Famille	Voisin	Autres	Gratuitement	Troc	Vente à crédit	Vente à comptant
Kibututu	9	9	53	6	9	6	9	4	4	2
Rugari	8	7	12	4	3	1	6	2	—	—
Kagara	12	3	4	2	1	—	3	1	—	—
Mushinga	23	23	442	18	22	21	23	—	—	3
Burhale	18	12	31	3	12	—	12	—	—	—
Ndundazi	2	2	12	1	2	1	2	—	1	1
Kayanja	4	4	27	1	5	2	3	2	1	1
TOTAL	76	60	581	35	54	31	58	9	6	7
en %	100 %	79 %	—	46 %	71 %	40,6 %				
% bénéf.			100%				97 %	15 %	10 %	12 %

Nous avons vite pu constater que les paysans sont ouverts aux autres, car pour la diffusion, nous avons enregistré que les variétés sélectionnées ont été cédées à 581 bénéficiaires. Le tableau 3 permet également de remarquer que la plupart des bénéficiaires (442/581, soit 76 %) se trouvaient à Mushinga.

La faible quantité de semences reçue après la sélection participative serait à la base de la faible diffusion des variétés dans les milieux enquêtés car les fermiers se préoccupaient d'en garder suffisamment pour leur propre production.

Un bon nombre d'agriculteurs ayant cédé leurs variétés à d'autres l'ont fait à titre gratuit (58/60 soit 97 %) ; 15 % (9/60) les ont données en troc ; 12 % (7/60) ont vendu leurs variétés au comptant (« cash ») et enfin 6 sur 60 interrogés (10 %) les ont vendues à crédit.

Vu la forte proportion des personnes ayant cédé gratuitement leurs variétés, il semble souhaitable d'étudier quelles contraintes doivent être levées pour pouvoir mettre sur pied un système organisé de production et de transmission de semences par les fermiers. L'intérêt d'un tel système semble être confirmé par les habitudes des agriculteurs relatives à l'approvisionnement en semences : l'enquête a révélé que 55 des 76 cultivateurs interrogés (72 %) mettent de côté une part de leur propre production, 32 (42 %) achètent leurs semences au marché et 17 agriculteurs (22 %) cherchent à s'approvisionner là où ils trouvent de bonnes variétés. On note ainsi qu'à Burhale, tous les agriculteurs ont l'habitude de s'approvisionner en semences au marché ; cela signifie qu'ils consomment et vendent toute leur production en risquant par là de perdre leurs bonnes variétés. Il serait souhaitable d'examiner cette situation pour en découvrir les causes réelles, afin de pouvoir trouver un système qui leur permettrait de conserver leurs variétés.

CONCLUSION

L'efficacité de la méthode participative semble avérée par les taux d'adoption en milieu paysan qui sont de 99 % pour le haricot volubile (tableau 1) et 97 % pour le haricot nain et semi-volubile (tableau 2). En effet, toutes les nouvelles variétés de haricot introduites pendant la sélection participative en 1993, ont été observées en culture trois ans plus tard, en 1996. Nous nous sommes cependant rendus compte que la faible quantité de semences distribuée au départ et utilisée par les paysans n'a pas permis d'évaluer l'impact réel sur le terrain. Nous pensons donc que lors de toute activité de sélection participative devrait être suivie d'une distribution en quantité suffisante des semences des variétés sélectionnées par les paysans.

Par ailleurs le transfert des nouvelles variétés a été un fait, une réalité, car l'on a constaté que des agriculteurs qui ne participaient pas à l'opération, avaient néanmoins bénéficié de l'expérience en obtenant des semences des variétés sélectionnées. Comme nous l'avons vu au tableau 3, 79 % des paysans interrogés ont partagé leurs semences, les transmettant à des membres de la famille, à des voisins ou à d'autres parties non définies.

BREEDING RED-MOTTLED BEANS FOR EAST AND CENTRAL AFRICA

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ABSTRACT

The common bean is grown by more than 90% of small-scale farmers in Africa. Of all the seed types grown in East and Central Africa, the red-mottled types occupy the greatest area: 650,000 ha in Eastern Africa and 90,000 ha in Southern Africa. This is also the most important bean type sold and consumed in Uganda, Kenya, Tanzania, Burundi, Malawi, Zambia, and Mozambique, with a market share of about 22% in Eastern Africa. The breeding programme in Uganda is aimed at developing improved, marketable, red-mottled varieties with resistance to two or more biotic and abiotic constraints, and with acceptable agronomic and culinary qualities. In order to achieve this objective, breeding activities have been implemented under five major projects: hybridisation, evaluation of segregating populations and new introductions, multilocational yield trials, on-farm testing, and maintenance breeding. Since 1995, eight varieties of bush beans and four climbing varieties have been released. Several others are in advanced stages and, currently, 10 bush and five climbing varieties are being tested on-farm. There have been high demand and adoption of these new varieties, thereby contributing to household food security, protein availability, and income. However, it has been observed that the selection criterion used by farmers is different from that used by breeders. There is now a need to involve farmers at the very early stage of selection through participatory plant breeding so as to accelerate the adoption process.

Key words: abiotic, biotic, bush beans, climbing beans, *Phaseolus vulgaris*, red mottled

RÉSUMÉ

En Afrique orientale et centrale, plus de 90 % des petits exploitants agricole cultivent le haricot commun et les variétés tachetées de rouge sont les plus répandues, couvrant 650 000 ha en Afrique de l'Est et 90 000 ha en Afrique australe. Elles sont également les plus couramment vendues et consommées en Ouganda, au Kenya, en Tanzanie, au Burundi, au Malawi, en Zambie et au Mozambique, avec une part du marché d'environ 22 % en Afrique de l'Est. Le programme de sélection réalisé en Ouganda a pour objectif de développer des variétés tachetées de rouge améliorées et commercialisables offrant une résistance à deux ou plusieurs contraintes biotiques et abiotiques et présentant des qualités agronomiques et culinaires acceptables. Pour atteindre ces objectifs, des activités de sélection ont été mises en œuvre dans le cadre de cinq projets principaux : hybridation, évaluation des populations en ségrégation et des nouvelles introductions, essais de rendement multilocaux, expérimentations en situation réelle et sélection conservatrice. Depuis 1995, huit variétés de haricots nains et quatre variétés volubiles ont été introduites. Plusieurs autres se trouvent à des stades avancés d'essai et actuellement 10 variétés naines et cinq volubiles sont testées en situation réelle. La demande de ces nouvelles variétés et leur adoption ont été importantes, ce qui a contribué à augmenter la sécurité alimentaire des familles et à fournir des protéines et des revenus. Il a toutefois été observé que les critères de sélection utilisés par les cultivateurs diffèrent de ceux des sélectionneurs. Il est donc nécessaire de faire participer les cultivateurs dès les toutes premières phases de la sélection au moyen de la sélection participative afin d'accélérer le processus d'adoption.

Mots clés : abiotique, biotique, haricots nains, haricots volubiles, *Phaseolus vulgaris*, tachetés de rouge

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INTRODUCTION

The common bean (*Phaseolus vulgaris*) is a major staple in Africa, where it serves as an important source of dietary protein, calories, zinc, and many other essential nutrients. It also plays an important role in generating income for small-scale farmers, particularly women. According to Wortman et al., (1998), there is diversity in terms of the market classes grown by farmers in the region, ranging from red mottled (calimas), red, navy, cream, yellow, black, purple, and brown. Red-mottled beans occupy the largest area of production: 740,000 ha in Africa. In East Africa, their production accounts for about 22% of total bean production. Red-mottled beans are also high to moderate in market preference in Kenya (Grisley and Munene, 1992), Uganda, Sudan, D.R. Congo, Tanzania, Zimbabwe, and Cameroon. However, most of the red-mottled varieties in the region, such as K 132 (CAL 96) in Uganda, K 20 (GLP 2) in Uganda and Kenya, and Urugezi in Rwanda, are susceptible to the major biotic and abiotic constraints affecting bean production. The most important biotic constraints include angular leaf spot (*Phaeosariopsis griseola*), common bacterial blight (*Xanthomonas campestris* pv. *phaseoli*), anthracnose (*Collectotrichum lindemuthianum*), and the root rots. Among the abiotic, low P is important.

Given the importance of this market class in the region, a breeding programme was initiated in Uganda to develop improved, marketable red-mottled bean varieties with resistance to two or more biotic and abiotic constraints, and with acceptable agronomic and seed quality characteristics for home consumption and the market. Both short- and long-term strategies were used, and four major activities were carried out during the seasons 2001A, 2001B, and 2002A; A refers to the first growing season (March-July) and B is the second growing season (September-December).

MATERIALS AND METHODS

Generation of segregating populations

A crossing programme for resistance/tolerance to multiple constraints was started as a long-term breeding strategy, focussing mainly on angular leaf spot, common bacterial blight, anthracnose, root rots, and low soil fertility. In addition, a back-crossing programme, specifically addressing resistance to angular leaf spot in two popular, but susceptible, red-mottled varieties (K 132 and K 20) was started using Mexico 54 as a source of resistance.

Evaluation of new introductions in observation nurseries

Two sets of red-mottled varieties, the first, comprising 160 bush-bean genotypes received from the regional programme on beans based at the University of Nairobi, was evaluated in 2001B, and the second, comprised of 100 genotypes, was evaluated in 2002A. Evaluation of new introductions was a short-term strategy used to widen the genetic base. These genotypes were first planted in observation nurseries at Namulonge Agricultural and Animal Production Research Institute in non-replicated fields, in plot sizes of two rows of 2 m/entry, spaced 50 cm between rows and 10 cm between plants. Data were recorded for such agronomic characteristics as days to 50% flowering, days to 90% physiological maturity, growth habit, and seed yield per plot. Their reaction to field diseases on the CIAT scale of 1 to 9 under natural infestation was also recorded. At the end of 2001B, 37 genotypes were selected from the first set for further evaluation. Selection was based on visual field observations of the pod load, reaction to field diseases, growth habit, seed size, and quality of the red-mottled colour. The 37 genotypes were further evaluated at Namulonge during 2002A in a replicated preliminary yield trial (PYT), in which red-mottled varieties, K 132 and POA 2 were included as local checks.

Constituting and evaluating a regional trial of advanced red-mottled bush-bean genotypes

Twenty advanced red-mottled bush-bean genotypes were constituted into a regional trial in Uganda for testing with other collaborating countries. The trial was distributed to Kenya, D.R. Congo, Rwanda, and Burundi during 2001 so as to compare the performance of the genotypes across the region. In Uganda, the genotypes were evaluated at two sites, namely Namulonge (central Uganda) and Kachwekano (south western Uganda) during 2001B. In 2002A, Nakabango (eastern) and Ngetta (northern) were added as additional trial sites. Plants were spaced at 50 cm between rows and 10 cm between plants in plot of 4 m x 1.5 m. Four red-mottled varieties released in Uganda—NABE 4 (POA 2), K 132, NABE 1 (OBA 1), and K 20—were used as checks.

Evaluation on farmers' fields

Two red-mottled bush-bean genotypes, POA 8 and AFR 623, were selected from the regional trial and tested on farmers' fields in the districts of Wakiso, Masaka, Lira, and Hoima to assess their acceptability and performance under real farmers' growing conditions. The two genotypes were tested along with several other seed types. Ten farmers were selected from each of the districts to participate. Each of the participating farmers was provided with five test genotypes, which included the two red-mottled genotypes. The farmers were required to include their own preferred variety as check, so the checks varied from farmer to farmer. Trial plots were 14 m² each. Farmers were required to observe the beans throughout the growing period, to cook and taste part of the harvest, and also to comment on the advantages and disadvantages of each genotype. Mid- and end-of-season evaluations were carried out.

Data analysis

The data collected from the introductions could not be statistically analysed because the trials were not replicated, due to limited seed quantities and also because of the number of entries. However, data from the other trials (which were replicated) were subjected to a proc GLM procedure (SAS, Version 8 for Windows). Data on farmers' comments was subjected to a logistic regression for preference ranking, using Microsoft Excel, Version 7.0 for Windows.

RESULTS AND DISCUSSION

Segregating populations

The number of seeds generated for each multiple-parent cross ranged from 49 to 152. Part of the seeds will be used for crossing with the elite red-mottled varieties, K 20, K 132, POA 2, and Urugezi. Another part will be directly selfed to generate F₂ segregating populations and subsequent generations for evaluation.

From the backcrossing programme, BC₁F₁ crosses—K 132 x F₁ (K 132 X Mexico 54) with 120 seeds and K20 x F₁ (K 20 x Mexico 54) with 97 seeds—had been generated by the end of 2002A.

Performance of new introductions

Reaction to field diseases under natural infestation

The most important field diseases recorded were angular leaf spot, rust, common bacterial blight, bean common mosaic virus, and ramularia (table 1).

In general, the scores of 1-3 suggest resistance and 4-6 suggest intermediate reactions. Very few genotypes were observed with scores of 7-8. However, these results from natural epiphytotics may not be very conclusive, and selected genotypes will be artificially inoculated in the following seasons.

Days taken to reach to 50% flowering and 90% physiological maturity

During 2001B, the 160 genotypes in set one took between 33 and 45 days to reach 50% flowering, and between 65 and 80 days to reach 90% physiological maturity. In 2002A, the 100 genotypes in set two took between 33 and 63 days to reach 50% flowering. In general, genotypes in set one appeared to be earlier maturing than those in set two.

Seed yield (kg) per plot, non-replicated

During 2001B, the seed yield of the 160 genotypes in set one ranged between 0.05 kg/plot and 0.42 kg/plot, while for set two, the 100 genotypes had a seed yield of between 0.40 kg/plot and 1.00 kg/plot. During 2001B, the final seed yield was affected by too much rainfall received towards the maturity stage of the crop, resulting in rotting and, hence, reduced yields.

Performance of the 37 selected genotypes in a PYT during 2002A at Namulonge

Significant differences ($p = .05$) were observed among the genotypes in the PYT during 2002A. The highest yielding genotypes were the check varieties POA 2 (with a mean seed yield of 917 kg/ha) and K 132 with a mean yield of 834 kg/ha. Among the test entries, the following were outstanding: BRB 149-1 and UBR (93)

Table 1. Scoring of Genotypes by Disease

	Score	Number
2001B (N = 160)		
Angular leaf spot	1-3	92
	7-8	68
Rust	2-3	148
	4-5	12
Common bacterial blight	2-3	7
	4-6	143
	7	10
Bean common mosaic virus	1-3	All
Ramularia	1-3	25
	4-6	117
	7-8	18
2002A (N = 100)		
Angular leaf spot	2-3	3
	4-6	82
	7-8	15
Rust	2-3	93
	4-5	7
Common bacterial blight	2-3	83
	4-6	7
Bean common mosaic virus	2-3	All
Ramularia	2-3	22
	4-6	76

Note: Plants were scored using the CIAT scale from 1 to 9, where
1 = no symptoms
3 = lesions on 5%-10% of the leaf area
5 = 20% or more of the leaf area infected and evidence of sporulation (depending on the disease)
7 = lesions on up to 60% of the leaf area and sporulation, associated with chlorosis and necrosis
9 = lesions on 90% of the leaf area, frequently associated with early defoliation and plant death.

37–1 (both with a mean yield of 778 kg/ha) and VTTT 926/1-2 (with a mean yield of 750 kg/ha). In general, these yields were low, which is attributed to the dry spell experienced before and after flowering. The most prevalent disease was angular leaf spot, and no genotype was observed with a resistant reaction (a score in the range of 1-3). On the other hand, some resistance was observed for the other diseases: rust, common bacterial blight, bean common mosaic virus, and web blight. The genotypes flowered between 35 and 43 days, while physiological maturity was between 62 and 89 days. This trial will be replanted at more sites in the following seasons, and promising genotypes will be shared with other partners for their own country-specific evaluation.

REGIONAL TRIAL OF RED-MOTTLED BEANS DURING 2001B AND 2002A

The agronomic performance of the genotypes in the regional trial in Uganda during 2001B and 2002A resulted in a mean seed yield ranging between 625 kg/ha and 1750 kg/ha across the two sites in 2001B. The three highest-yielding test genotypes were AND 907 (1750 kg/ha), AFR 735 (1667 kg/ha), and AND 1005 (1445 kg/ha). During 2002A, the mean yield ranged between 746 kg/ha and 1701 kg/ha. Genotypes CAL 143 (1670 kg/ha), AND 907 (1427 kg/ha), and CAL 176 (1569 kg/ha) had the highest seed yields across seasons. However, these high-yielding genotypes did not have attractive red-mottled colours and the growth habits were also poor, so they could not be selected for further testing on farmers' fields. Therefore, moderately yielding genotypes POA 8 and AFR 623 were selected for farmers' fields because at least their appearance was better.

Performance of POA 8 and AFR 623 on farmers' fields

Mean yield of the red-mottled genotypes compared to other seed types

The mean seed yields of the two red-mottled genotypes (POA 8 and AFR 623) are presented in table 2, compared to other seed types. Across the four districts, POA 8 had the highest yield (1230 kg/ha), which was 77% over the farmers' checks. AFR 623 was 71% higher.

Table 2. Mean Seed Yield of Genotypes Tested on Farmers' Fields in Four Districts

Genotype	Seed colour	Mean seed yield (kg/ha)				Mean across districts	Mean as % of farmers' check
		Masaka	Lira	Wakiso	Hoima		
DRK 126	Dark red	871	833	938	396	760 c	109
POA 8	Red mottled	1250	1215	2153	301	1230 a	177
DFA 58	Medium red	*	1007	1424	490	974 ab	140
AFR 721	Sugar	1333	1250	1909	326	1205 a	173
PAD 126	Red	1158	799	1528	437	981 ab	141
AFR 623	Red mottled	1375	1042	2153	180	1188 a	171
Farmers' check	Varied	1071	938	590	186	696 c	100**

*Not tested in Masaka.

**Farmers' check was assumed to be at 100%.

Acceptance of red-mottled genotypes by farmers, compared to the other genotypes

POA 8 and AFR 623 were among the three genotypes most preferred by farmers. After AFR 721, they had a high probability of being ranked first.

Some of the reasons the genotypes were ranked highly include the following:

- **POA 8:** It had a high yield potential and was tolerant to drought. It was also tolerant to very heavy rains, according to some farmers. The seed colour was acceptable although the seed size was smaller, compared to K 132 (a popular red-mottled release grown by farmers). Some farmers thought that despite the seed size, it still had market potential. On cooking, it was tasty.
- **AFR 623:** Its yield potential was good, and it was also marketable. However, it was a bit late maturing. The soup colour was good on cooking.

CONCLUSION AND WAY FORWARD

Results of the 2001/2002 breeding activities for the red-mottled beans reported here indicate that there is potential to provide farmers with higher-yielding red-mottled bean varieties from the programme. Populations segregating for tolerance/resistance to multiple constraints were generated and will continue to be used in the crossing programme. Introductions were evaluated to assess their performance and identify superior ones. Any promising genotypes identified will be shared with partners. Genotypes POA 8 and AFR 623 from the regional trial suited farmers' needs in Uganda. However, there is a need to get information on their performance in the region. Activities are also underway to collect data on the regional trial from all partners.

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NAVY-BEAN BREEDING FOR SMALLHOLDER FARMERS IN EASTERN AND CENTRAL AFRICA

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ABSTRACT

Common beans are among the major grain legumes grown in most parts of Eastern and Central Africa as a source of cheap protein and cash, and for their restorative effects in cereal-dominated cropping systems. Among the several market classes of beans grown in the region, the navy type (white, small-seeded), characterised by high canning quality, is produced mainly as an export crop in Ethiopia, where the two major areas of production account for about half of the total bean production in the country. The amount of beans exported by Ethiopia since 1993/94 and 1997/98 has been increasing and has averaged over US\$16 million per annum. However, productivity is very low because of low soil fertility, poor agronomic practices, and the use of low-yielding varieties susceptible to diseases and insect pests. In the 1970s, a nationally coordinated research project was started in Ethiopia to improve the productivity of navy bean varieties with desirable seed characteristics and tolerance to major biotic and abiotic constraints. Breeding strategies that properly and adequately address the problems of the narrow genetic base, lack of varieties tolerant of multiple constraints, lack of high-yielding varieties with acceptable seed quality, and susceptibility to diseases and insect pests are needed.

RÉSUMÉ

Le haricot commun fait partie des légumineuses à grains les plus cultivées dans la majeure partie de l'Afrique orientale et centrale. Il a l'avantage d'être source de protéines bon marché et de revenus, tout en ayant un effet régénérateur sur les systèmes culturaux où les céréales prédominent. Parmi les nombreuses catégories commerciales de haricots cultivés dans cette partie de l'Afrique, le haricot rond blanc (à petites graines), convenant parfaitement à la mise en conserve, est produit essentiellement en Éthiopie en tant que culture d'exportation. La moitié de la production totale de haricots du pays s'y concentre dans deux principales régions. Les quantités exportées par l'Éthiopie depuis les années 1993-1994 et 1997-1998 ont augmenté et correspondent en moyenne à plus de 16 millions de dollars américains par an. La productivité est toutefois très médiocre du fait des sols peu fertiles, des mauvaises pratiques agricoles et de l'utilisation de variétés à faible rendement et sensibles aux maladies et aux insectes ravageurs. Dans les années 1970, un projet de recherche coordonné au niveau national a été lancé en Éthiopie pour améliorer le rendement des variétés de petits haricots ronds blancs afin d'obtenir des graines aux caractéristiques souhaitées et offrant une tolérance aux principales contraintes biotiques et abiotiques. Les chercheurs du département de socio-économie du Centre de recherche de Melkassa savaient qu'il n'existait aucune information appropriée et recueillie de manière systématique sur les taux d'adoption et l'impact des variétés améliorées de petits haricots ronds sur la sécurité alimentaire des familles, les protéines disponibles et les revenus générés. Ils ont donc prévu une étude approfondie sur ces questions au cours de l'année culturale en cours. Par rapport aux ressources et aux efforts investis, le nombre de variétés améliorées de petits haricots blancs introduites jusqu'à présent n'est pas très satisfaisant. Il est donc nécessaire de développer des stratégies de sélection qui répondent de manière adéquate aux problèmes de l'étroitesse de la base génétique, du manque de variétés tolérantes aux multiples contraintes, du manque de variétés à haut rendement aux graines de qualité acceptable et suffisamment résistantes aux maladies et aux insectes ravageurs.

INTRODUCTION

Navy bean production and importance in the region

Beans are grown throughout much of Africa, with production concentrated in the eastern and central highlands (Voyses and Dessert, 1991). They are grown as varietal mixtures for a number of possible reasons, including minimisation of risk in growing several varieties and lack of market pressure for a uniform product since a relatively small proportion of production is marketed. However, in areas where production is more market-oriented, such as for export or processing, production of pure varieties does take place.

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Table 1. Estimated Area Sown Annually to Nine Categories of Bean Seed Types in Africa

Seed category	Production (thousands of hectares)	
	East Africa	Southern Africa
Calimas	650	90
Reds, small and medium-sized	510	160
Reds, large and kidney	230	120
Yellows and tans	290	90
Creams	240	120
Navy	190	120
White, large and medium-sized	130	90
Purples	150	120
Blacks	100	30

Source: CIAT (2001).

There are definite regional differences in preferences for types of beans—for both production and consumption. Navy beans (white, small seeded) are among the most important category grown, accounting for about 9% of the area devoted to bean production in Africa (table 1). Also known as ‘small white’ or ‘pea beans’ and as the ‘Michigan type’ in the export market, navy beans yield well not only under low-input conditions but also under conditions of stress from low moisture (Wright and Redden, 1998) and are the major type grown in the Rift Valley and mid-altitude Hararghe regions of Ethiopia, mid-veldt of the Republic of South Africa, and Guinea (Wortmann et al., 1998). They are also grown on a medium scale in parts of Uganda, Kenya, Madagascar, DR Congo, Tanzania, Sudan, and Ethiopia.

Navy beans are a good source of cholesterol-lowering fibre, which prevents blood-sugar levels from rising too rapidly after a meal, making these beans an especially good choice for individuals with diabetes, insulin resistance, or hypoglycemia. When combined with whole grains, such as rice, navy beans provide high-quality, virtually fat-free protein. Navy beans are a very good source of folic acid and manganese and a good source of protein and vitamin B1, as well as the minerals phosphorus, copper, magnesium, and iron (Serre, 2002). The navy bean got its name because it was a staple food of the United States Navy in the early 20th century.

The high demand for navy beans, for export, canning, and urban markets (due to their taste and relatively short cooking time), is expected to raise production.

Commercial, small-farm production of navy beans for canning (mainly for export to the Middle East) has long been the dominant pattern in the Rift Valley and Hararghe areas of Ethiopia, bringing between US\$16 and US\$20 million per year into the country. There are also larger scale producers in South Africa and Zimbabwe (Wortmann et al., 1998), which offer potential markets for countries that are members of the Eastern and Central Africa Bean Research Network ECABREN, whereas Madagascar, Ethiopia, Tanzania, Uganda, and Sudan export navy-type beans to both regional and international markets.

Production constraints

The perceived nutritional, agronomic, and economic benefits of navy beans are expected to increase the demand for new and improved varieties, but despite the multiple advantages of navy beans as discussed above, productivity remains low because of several stress factors, both biotic (rust, common bean blight, angular leaf spot, anthracnose, bean stem maggot) and abiotic (drought, low P and N, low pH). In contrast to other bean types, only a few improved cultivars of navy beans have been released and made available for growers in the region. Out of a total 24 common bean cultivars released by the National Bean Research Program of Ethiopia, only three belong to the small white (navy bean) type (table 2).

In fact, the number of improved navy bean varieties so far released is inadequate, considering the resources invested in genetic manipulation, evaluations of segregating materials, and introductions undertaken at various locations. Key bottlenecks are related to the narrow genetic base of the crop, lack of varieties tolerant to multiple constraints, lack of high-yielding varieties with acceptable canning qualities, and susceptibility to diseases and insect pests.

Table 2. Common Bean Cultivars Released by the National Bean Research Program of Ethiopia in Collaboration with CIAT

Year of Release	Total	New Name	Original Identification or Code	Type of Germplasm*	Genealogy
2003	1	MAM 48	MAM 48	2	A 785 x ([G 4495 x G 8086] x [BAC 16 x WILKINSON 18])
2003	2	IBADO	AFR 722	2	
2003	3	DOR 554	DOR 554	2	DOR 364 x SEL 1073
2003	4	DICTA 105	DICTA 105	2	
2002/2003	5	OMO 195	RWR 719	2	
2001	6	AFR 504	AFR 504	2	G 20554 x XAN 122
2001	7	A 197	A 197	2	G 76 x G 21721
1999	8	PAN 173	PAN 173	2	BAT 1684 x XAN 135
1999[†]	9	Awash Melka	PAN 182	2	BAT 304 x G 5652
1999	10	ICA 15541	Bred by Colombia	5	
1999	11	MX 2500-19	Introduced via CIAT	3	
1999	12	Tabor	A 788	2	(BAT 85 x [A 338 x G 5054]) x (A 252 x XAN 87)
1999	13		A 776	2	(BAT 477 x G 5019) x (G 4017 x XAN 40)
1999	14	GX 1175-3	Introduced via CIAT	3	
1999	15	TY 3396-7	Introduced via CIAT	3	
1998	16	Besh besh	XAN 76 x BAT 85	3	
1998	17	Melkie	CAL 113 x AND 829	3	
1997	18	Zebra	A 162	2	G 11893 x A 32
1997	19	A 262	A 262	2	G 4017 x G 2618
1997	20	Gofta	G 2816	1	
1991	21	A 410	A 410	2	G 4017 x G 2618
1989	22	Roba 1	A 176	2	G 7951 x A 30
1989	23	Awash 1	G 4445	1	
1972/1973	24	Mexican 142	G 11239	1	

Source: CIAT (2001).

Note: Rows shown in bold text are cultivars of navy beans.

* 1 = GRU accession

2 = CIAT line

3 = CIAT cross locally selected

4 = NARS cross with CIAT parent

5 = Varieties or advanced lines from NARS distributed through CIAT network

6 = Selection on local varieties or land races

ACHIEVEMENTS IN NAVY BEAN BREEDING—LESSONS FROM ETHIOPIA

At the inception of a coordinated bean-improvement research programme in 1972, local collections (mainly from market samples and bean traders) were tested with other introduced accessions at several locations in Ethiopia. Among the navy beans, three varieties (Mexican 142, Tengeru 16, and Ethiopia 10) were recommended and accepted for the export market. In 1983, the varietal selection programme was reoriented to aim at developing improved varieties for both export and local demand. Most of the best-performing navy bean varieties identified between 1983 and 1986, however, were rejected because of their poor canning quality. Beginning in 1987, germplasm introductions were increased greatly and there was a rapid flow of promising varieties in the selection scheme. Such an aggressive approach to germplasm advancement led to the release of a new variety, Exrico 23 (renamed 'Awash-1') in 1990.

In recognition of the relative scarcity of navy bean germplasm available throughout the world for introduction and evaluation, and export market demands for large quantities of a uniform type, a stronger and more focused crossing programme was launched in 1990 to increase the frequency of cultivar release. As a result, a variety

with high canning quality and resistance to anthracnose, named Awash Melka, was released in 1999. The application process has already been started for official approval for the release of candidate genotypes such as EMP 233, UTT 27-24, and NZBR-2-8, which have exhibited consistent superior performance over the currently available varieties in the national yield trials.

Over the 30 years of work developing navy bean varieties, genetic variability has been generated through back crossing, mutation breeding, and double-crossing, followed mainly by single-plant selections in segregating generations. The scheme followed for the evaluation of fixed crossing lines and introduced materials from early to advanced stages were nursery I, nursery II, Prenational Variety Trial, National Variety Trial, Variety Verification (on-station and in farmers' fields), and the request for approval for the release of a new variety.

Performance of cultivars across diverse environments

Navy beans are grown across the diverse bean-growing agro-ecologies of Ethiopia, although production is concentrated in the eastern and central Rift Valley regions. National yield trials usually cover all regions represented by research centres or testing sites. Analyses of genotype x environment (GXE) interactions and stability have been undertaken employing a regression model and using 16 navy bean genotypes grown at four (Gebeyehu and Assefa, 2003) and seven (Gebeyehu and Assefa, unpubl.) locations in order to generate information for efficient allocation of resources in future cultivar-testing programmes.

Most test genotypes were sensitive to production-limiting factors: their wider adaptability, stability, and general performance were lowered in relation to the fluctuating growing conditions within and across sites in both studies. In general, the highest-yielding genotypes appeared less stable than the average of all lines, and selection solely for yield could result in discarding many stable genotypes. Similarly, selection indices identified stable genotypes, but these yielded slightly less than genotypes selected solely for yield. Not disregarding the possibility of obtaining genotypes with wide adaptation at the expense of exceptionally high yield at specific sites, the decentralisation of cultivar testing (already begun by the National Bean Research Program in order to develop navy bean cultivars with specific adaptation to the major bean growing regions) is a laudable strategy for improving the efficiency of cultivar release. Considering the wide variations in edaphic, climatic, and farming systems among the major navy bean-growing regions of Eastern and Central Africa, cultivars specifically adapted to the prevailing growing conditions need to be developed, along with extensive information sharing and exchange of genetic materials among the national bean research programmes.

SUMMARY OF PROPOSED RESEARCH ON IMPROVING NAVY BEAN CULTIVARS FOR SMALLHOLDER FARMERS OF EASTERN AND CENTRAL AFRICA

In view of meeting the increasing demand for export to both regional and international markets, the breeding programme outlined below (table 3) is proposed to increase the productivity and commercialisation of the navy bean for improving both farmers' income and household food security in the region.

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Table 3. Proposed Breeding Programme

Objective	Develop high-yielding navy bean varieties for Eastern and Central Africa with desirable seed quality characteristics and tolerance to major biotic and abiotic constraints
Methodology	Modified backcross inbred/double-cross method
Materials	<ul style="list-style-type: none"> • Core collection from CIAT headquarters (small white) • Commercial cultivars with universal appeal • Any other sources of resistance
Major Outputs	<ul style="list-style-type: none"> • Segregating populations for distribution to NARS • Advanced lines for further evaluation by NARS • New navy bean with desirable seed characteristics and tolerance/resistance to major biotic and abiotic constraints
Programme Leader	Regional breeder
Co-leader	National Lowland Pulse Research Program, Ethiopia
Collaborators	<ul style="list-style-type: none"> • Kenya, Sudan, Uganda, Tanzania, DR Congo • CIAT – Africa pathologist • Headquarters: breeders and pathologist
Location/sites:	
Core breeding	Ethiopia
Test sites	Kenya, Sudan, Uganda, Tanzania, DR Congo
Targets/Milestones	
Dec 2000	<ol style="list-style-type: none"> 1. Build up working collection for navy bean lines with genes for resistance to rust, angular leaf spot, anthracnose, common bean blight, root rot, and bean common mosaic virus 2. Grow an observation nursery of the working collection and increase seeds 3. Make single crosses between commercial susceptible cultivars and sources of resistance
Dec 2001	<ol style="list-style-type: none"> 4. Conduct preliminary yield trials for lines selected from the working collection and other populations and local commercial checks at two sites per country in two countries 5. Crossing programmes for navy beans in place in at least one country using at least two susceptible parents grown by navy bean exporters 6. F₂ populations screened for combinations of priority constraints
Dec 2002	<ol style="list-style-type: none"> 7. Advanced yield trials conducted concurrently on-station and on-farm for advanced lines: two sites per country in at least two countries (i.e., one on-farm and one on-station) in collaboration with exporters 8. F₃ lines selected from the F₂ and backcross populations 9. Recombinant F₄ lines from regional crossing programme available to at least three NARS
Indicators	<ol style="list-style-type: none"> 1. At least five new navy bean lines and selections (from the working collection) grown in observation nurseries in two countries by July 2001 2. At least two F₂ navy bean populations combining two or more priority constraints created from regional crossing programmes by December 2001 3. Preliminary yield trials of advanced lines (from working collections) conducted at two sites in two countries by December 2001 4. Crossing and selection programmes for navy bean cultivars operational in at least one country by December 2002 5. At least two F₄ lines combining two or more priority traits identified from on-station and on-farm early-generation trials in two countries by December 2002

RÉPONSE DU HARICOT (*PHASEOLUS VULGARIS* L.) AU COMPOST SUR DES SOLS COLONISÉS PAR DIVERSES HERBES SPONTANÉES

Ngongo Mulangwa

RÉSUMÉ

*Le rendement du haricot (variété VCB810120) a été évalué avec et sans compost sur des parcelles colonisées par certaines herbes naturelles que les paysans du Sud-Kivu considèrent comme étant des indices soit de fertilité (*Galinsoga parviflora*), soit d'infertilité (*Pennisetum polystachia*). Il ressort de l'étude que, sur un sol colonisé par *Galinsoga parviflora*, l'application du compost est sans effet par rapport au témoin : comme, sur ce sol, le rendement du haricot est élevé aussi bien dans le cas du témoin (1 700 kg/ha) que de la parcelle amendée (1 713,3 kg/ha), on peut déduire que *Galinsoga parviflora* témoigne bien d'un bon niveau de fertilité. Par contre, sur une parcelle dominée par *Pennisetum polystachia*, l'apport du compost a un effet très significatif sur le rendement du haricot. Toutefois, puisque ce rendement amélioré demeure néanmoins faible, la conclusion s'impose que l'efficacité du compost est très limitée lorsqu'on l'applique sur un sol aussi dégradé que le sol dominé par cette végétation spontanée.*

ABSTRACT

*The effect of compost on bean yields was tested by cultivating the VCB810120 variety on plots colonised by wild plants which farmers in South-Kivu consider to be an indication of either soil fertility (*Galinsoga parviflora*) or infertility (*Pennisetum polystachion*). Findings showed that the use of compost on soils dominated by *Galinsoga parviflora* had no noticeable effect compared with the pilot plot: bean yields were high with and without compost (1,700 kg/ha vs. 1,713.3 kg/ha), which led to the conclusion that *Galinsoga parviflora* is indeed indicative of a high level of fertility. On the other hand, the impact of compost on a plot dominated by *Pennisetum polystachion* proved to be significant, the yield increase being much higher. However, since the increased yield was still low, one may conclude that the effectiveness of compost is very limited when soils are as degraded as those dominated by *Pennisetum polystachion*.*

INTRODUCTION

Dans notre région, celle du Sud-Kivu en République Démocratique du Congo, l'amendement organique, et notamment le compost, constitue un complément ou même une mesure palliative pour remplacer des engrais minéraux, rares et chers. Or le recours au compost pour fertiliser des terres à plus ou moins grande échelle est malheureusement limité par le problème des quantités relativement importantes (10–20 t/ha) généralement requises pour obtenir un effet palpable. Il importe donc que cet amendement, même s'il est peu onéreux, soit appliqué de façon rationnelle. Comme c'est le cas pour tout fertilisant, une telle utilisation judicieuse implique, outre la fixation des doses optimales, une prise de décision à partir de bases fiables.

OBJECTIF

Le but de la présente étude, qui se poursuit toujours, est d'élaborer une méthode—fiable et à la portée de tous (y compris des paysans)—pour guider le choix soit d'utiliser le compost, soit de s'en passer pour en éviter le gaspillage, ce dans le cadre de la culture du haricot. En d'autres mots, il s'agit d'une méthode de prédiction du comportement du haricot en réponse au compost, méthode qui se base sur la connaissance paysanne et consiste à évaluer les sols en considérant la présence dominante de certaines herbes considérées comme indicatrices du niveau de fertilité.

MATÉRIEL ET MÉTHODE

L'étude a été conduite en milieu rural, à Walungu dans le Sud-Kivu. Elle portait sur deux facteurs principaux : l'espèce de végétation spontanée dominante et l'amendement organique (compost). Le dispositif

expérimental était un dispositif en split-plot. La variété de haricot plantée était la variété VCB81012 de haricot volubile, en diffusion dans le milieu ; elle fut semée avec ou sans compost, la dose utilisée étant de 20 t/ha). Les essais étaient menés dans différents villages sur des parcelles de sols où dominait à chaque fois l'une ou l'autre des herbes qui faisaient l'objet de l'étude, à savoir les espèces *Galinsoga parviflora*, *Pennisetum polystachia*, *Conyza sumatrensis*, *Bidens pilosa* et *Digitaria vestida var scalarum*. Ces herbes étaient donc éparpillées à différents endroits et, à la récolte, l'on a soigneusement enregistré pour chaque parcelle, le rendement du haricot, le traitement (avec ou sans compost) et la végétation dominante.

RÉSULTATS ET DISCUSSION

Le Tableau 1 présente l'effet du compost sur le rendement du haricot en graines sur différents sols caractérisés chacun par l'espèce d'herbe la plus représentative (75% de dominance) de l'association végétale spontanée en place.

Selon les paysans, la dominance sur un sol des herbes *Galinsoga parviflora* et *Bidens pilosa* constitue un signe de bonne fertilité, tandis que celle de *Pennisetum polystachia* et de *Conyza sumatrensis* caractériserait les sols pauvres ((Ngongo, 1995). Globalement, les résultats des essais semblent vérifier cette évaluation paysanne. On constate en effet que, sur les sols colonisés par les végétations dites indicatrices de fertilité (*Galinsoga parviflora* et *Bidens pilosa*), le rendement du haricot ne fut pas influencé de manière significative par l'épandage du compost. Déjà sans compost, les meilleurs rendements du haricot enregistrés étaient ceux obtenus sur des parcelles où dominaient *Galinsoga parviflora* (1 700 kg/ha), *Digitaria vestida var scalarum* (1 251,2 kg/ha) et *Bidens pilosa* (873,3 kg/ha). L'épandage de compost sur des sols colonisés par ces trois herbes ne donna que des accroissements négligeables. Dans le cas de la dominance par *Galinsoga parviflora*, le rendement du haricot augmenta de 13,3 kg/ha, tandis que l'augmentation fut de 84,3 kg/ha pour *Digitaria vestida var scalarum* et de 60,0 kg/ha dans le cas de *Bidens pilosa*. Cela semble témoigner du bon niveau de fertilité naturelle des sols cultivés.

Tableau 1. Rendement du haricot (VCB81012) tel qu'influencé par le compost sur des sols colonisés par diverses herbes spontanées

Nom scientifique	Nom vernaculaire (*)	Rendement (kg/ha)		Accroissement (hg/ha)
		Avec Compost	Sans Compost	
<i>Pennisetum polystachia</i>	Mucira wa mbwa	696,7cd	41,7e	655,0
<i>Conyza sumatrensis</i>	Nyambuba	827,7c	417,7d	408,0
<i>Bidens pilosa</i>	Kashisha	933,3c	873,3c	60,0
<i>Digitaria vestida var scalarum</i>	Musihe	1335,3b	1251,0b	84,3
Moyenne		1101,3	857,1	244,1
Coefficient de variation (%)		21,2	24,2	

* En dialecte "Shi" parlé dans l'est de la RDC.

Les chiffres suivis de lettres semblables au moins ne diffèrent pas significativement au point $p \leq ,05$.

Par contre, sur les sols où dominaient *Pennisetum polystachia* et *Conyza sumatrensis*, herbes dites indicatrices d'infertilité, l'on a enregistré des accroissements de rendement de haricot substantiels (655 kg/ha dans le premier cas et 408 kg/ha dans le second) suite à l'application du compost, ce qui témoigne de la pauvreté des sols de départ. Il convient toutefois de remarquer que sur ces sols, le rendement maximum de haricot volubile obtenu avec du compost reste assez bas, soit la moitié de celui obtenu sans compost sur les sols colonisés par *Galinsoga parviflora* et *Bidens pilosa*.

Les sols des parcelles dominées par *Pennisetum polystachia* et *Conyza sumatrensis* étaient tellement dégradés et limitatifs pour la culture du haricot que la productivité du haricot sans amendement s'est avérée très faible, soit 41,7 kg/ha là où dominait *Pennisetum polystachia* et 419,7 kg/ha sur les terres dominées par *Conyza sumatrensis*.

CONCLUSION PARTIELLE

Les premiers résultats de l'étude montrent ainsi que, sur le sol d'un terrain dominé par les herbes spontanées *Galinsoga parviflora*, *Bidens pilosa* et *Cynodon dactylon*, l'application du compost constituerait un gaspillage.

Par contre, en cas de dominance des herbes *Pennisetum polystachia* et *Conyza sumatrensis*, le haricot répond de manière remarquable au compost.

Il semble donc bien que ces résultats viennent corroborer la connaissance paysanne selon laquelle la dominance de *Galinsoga parviflora* ou de *Bidens pilosa* indiquerait un bon niveau de fertilité tandis que celle de *Pennisetum polystachia* ou de *Conyza sumatrensis* caractériserait les sols pauvres.

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EVALUATION OF ROOT GROWTH ON DRY BEANS (*PHASEOLUS VULGARIS* L.) UNDER CONDITIONS OF WATER STRESS

Wilson Ronno

ABSTRACT

*Trough studies were conducted to evaluate the response to water stress of root growth in dry bean (*Phaseolus vulgaris* L.) genotypes over a period of two seasons. Thirty-six genotypes collected from the major bean-growing areas of Kenya were subjected to two watering levels. Taproot length (TRL) and root dry weight (RDW) were measured. Results indicated significant genotypic differences in both parameters. Water-stressed plants manifested faster growth in taproot length but the roots had lower dry weights than the non-stressed plants. This study identified previously unreported sources of superior root growth under conditions of water deficits in early-maturing dry beans in Kenya.*

RÉSUMÉ

*Durant deux saisons consécutives, des études ont été réalisées afin d'évaluer la réponse au stress hydrique de la croissance racinaire dans des génotypes du haricot sec (*Phaseolus vulgaris* L.). Trente-six génotypes provenant des principales régions de culture du haricot au Kenya ont été soumis à deux niveaux d'arrosage différents. La longueur de la racine pivotante ainsi que le poids sec de la racine ont été mesurés. Les résultats indiquaient des différences génotypiques importantes pour les deux paramètres. Les plantes soumises au stress hydrique montraient une croissance plus rapide de la longueur de la racine pivotante tandis que les racines avaient des poids secs moins élevés que les plantes qui n'étaient pas soumises au stress hydrique. Cette étude a identifié des sources inédites de croissance racinaire supérieure dans des conditions de déficit hydrique pour le haricot sec à maturation précoce au Kenya.*

INTRODUCTION

Production of dry beans per unit area varies from season to season and year to year, mostly because of inadequate soil moisture during the growing season. Drought stress often affect the plant's physiological and metabolic processes, leading to poor crop performance (Begg and Turner, 1983; Kramer, 1983).

The development of an optimum production system for dry beans in semi-arid environments involves breeding and selecting genotypes best suited to the environment and developing cultural practices to manage plants according to the environment. Levitt (1980) suggested that physiological indicators of plant stress, such as relative water content (RWC) and leaf water potential (LWP), provide an approximate measure of resistance within a group of plants under a similar set of conditions. Success in breeding varieties adapted to water-stressed environments has been achieved with early-maturing varieties and drought-escape mechanisms.

Although direct selection for seed yield under soil moisture stress can result in genetic gain, yield alone may be a poor measure of a particular stress because, in the field, yield reflects the effect of a combination of many factors. However, dry bean varieties developed according to drought tolerance, with high or low plant water potential, *per se*, are limited. There is a need, therefore, to incorporate other mechanisms of drought tolerance, in addition to early maturity, to enhance and stabilise yields.

Identifying genetic variability and selecting genotypes with long, extensive root systems can contribute to better performance in water-stressed environments because such plants would have an enhanced ability to go through mid-season and late-season dry spells.

The main objective of this study was to determine differences in dry-bean genotypes under different water regimes, based on root growth.

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REVIEW OF LITERATURE

Tolerance of dehydration with a high water potential is characterised as the ability of a plant to endure periods of water deficit while maintaining a high water potential in its tissue. This occurs by physiological or morphological modifications that maintain water uptake (for example, greater root growth and increased hydraulic conductance). An increase in root weight may indicate a greater density or a greater depth of the roots (Turner, 1979); both are important morphological adaptations to water deficits in beans, enabling a greater degree of extraction of soil water (White and Izquierdo, 1991). Drought tolerance has been found to be due to the maintenance of high water status through deep roots and water retention in the plant. For example, drought tolerance arising from deeper root penetration under water-stressed conditions has been demonstrated in varieties BAT 477 and Carioca (Guimaraes, 1986); Ulonzo, White Haricot, and GLP1004 (Runkulatile et al., 1993); in beans and sorghum (Al-Karaki et al., 1995); sorghum (Blum, 1988; Omany et al., 1996); and tepary bean (Markhart, 1985). Greater root proliferation would also allow exploration of a greater soil volume and would help the plant to survive under conditions of soil water deficits (Parsons, 1982). For example, in maize, the development of a highly branched root system that is large in relation to the shoot may ensure an adequate supply of moisture, thereby enabling genotypes to realise their inherent yield potential (Richner et al., 1997).

In addition to large root systems, plants must also have low root resistance to water flow between the root and leaf (Hale and Orcutt, 1987; White and Izquierdo, 1991). This can be achieved by increasing the number of xylem vessels without increasing their diameter (Turner, 1979).

MATERIAL AND METHODS

The experiment was conducted at Kiboko (975 m above sea level, 2° 12' S and 37° 43' E). Thirty-six genotypes (table 1) were evaluated for taproot length (TRL) and root dry weight (RDW) under two water regimes in a trough experiment. Troughs were constructed of baked bricks and filled with field soil. Each trough measured 10.8 m x 3.5 m by 1.2 m high. All troughs were fully irrigated to field capacity prior to planting to facilitate uniform germination. The procedures for calculating the amount of water required per trough were adopted from Doorenbos and Pruitt (1977).

No additional irrigation was applied to the water-stressed treatment (WST). The non-stressed treatment (NST) was maintained at near field capacity throughout the experimental period by applying water every two to three days.

The experiment was designed as a split plot with irrigation treatments allocated to the main plots and the genotypes to the sub-plots. In all treatments, seeds were planted 30 cm between rows and 15 cm within the rows. Appropriate steps for fertility and crop protection were taken to maintain a healthy crop.

Root length and root dry weight were monitored on two occasions, namely, 15 DAE (representing seedling development) and 36 DAE (representing pod development). At each sampling date, troughs were well watered about six hours prior to sampling to allow easy removal of the bricks without interfering with the roots. At sampling time, the bricks bordering one side of each trough were carefully removed, exposing the roots. Each plant was then carefully dug out and immersed in a container of water to soak and remove the soil surrounding the roots, which were then measured for length by using a ruler. The roots were subsequently severed at the stem base and oven dried to determine root weight. Six plants in each plot were harvested to obtain these measurements.

All data for irrigated (NST) and non-irrigated (WST) treatments were analysed using the general linear models (GLM) procedure of SAS (SAS Inst., 1988) and analysis of variance (ANOVA) following procedures described by Steel and Torrie (1980). Genotype means were separated by Duncan's Multiple Range Test (DMRT).

RESULTS

Genotypic differences in root growth, as measured by TRL and RDW at the two monitoring occasions, were observed in both watering regimes. However, higher genotypic differences were observed under the WS treatment than the NS treatment at both monitoring occasions.

Under the water-stress treatment (WST) at seedling stage, 15 days after emergence (DAE), taproot length generally grew rapidly but accumulated less root dry weight than was found in the non-stress (NST) treatment (tables 1 and 2). However, at pod development (36 DAE), both the TRL and RDW values were

Table 1. Growth Habit, District of Origin, and Means for Taproot Length of Thirty-Six Dry-Bean Genotypes Measured over Two Seasons

Genotype	Growth Habit	District of Origin	Taproot length (cm)			
			15 Days after emergence		36 Days after emergence	
			WS	NS	WS	NS
1	I	Machakos	56.0 bed	44.7 a-g	57.7 l-p	76.7 a-d
2	II	Kitui	59.3 ab	50.7 ab	82.0 a	80.3 a-d
3	II	Kisii	40.7 k-n	38.7 e-m	58.3 op	80.3 a-d
4	II	Embu	58.7 ab	37.3 g-n	72.8 j-o	79.0 a-d
5	I	Kakamega	51.7 c-g	40.7 d-l	65.3 c-i	68.3 a-d
6	I	Kakamega	44.7 h-c	46.3 a-e	49.3 j-p	62.0 d
7	II	Nyeri	44.7 h-c	42.7 b-k	55.7 f-n	76.7 a-d
8	II	Kirinyaga	63.9 a	47.3 a-d	81.0 ab	80.2 a
9	I	Kitui	43.7 i-m	41.7 c-k	67.0 c-g	64.7 c-d
10	I	Nyeri	46.3 f-e	37.7 f-m	51.3 j-o	82.7 a-d
11	II	Kisii	41.3 k-n	38.0 f-m	56.0 f-m	66.7 a-d
Kat B9	I	Makueni	51.3 c-h	45.3 a-g	75.7 a-d	78.7 a-d
GLP x 92	II	Machakos	53.3 b-e	44.3 a-g	73.0 a-e	62.0 d
GLP 1004	I	Machakos	57.0 bc	41.0 d-l	60.2 g-n	80.3 a-d
Okuodo	II	Kisumu	43.7 i-m	40.0 d-m	46.3 m-p	75.3 a-d
16	II	Kitui	46.7 e-k	38.3 e-m	62.0 e-k	66.0 a-d
Kat B1	I	Makueni	52.3 c-f	42.7 b-k	80.3 ab	89.3 abc
GLP 2	I	Ex-Kawanda	40.3 k-n	51.0 a	61.0 e-l	72.0 a-d
19	II	Kakamega	41.7 k-n	36.0 h-n	60.3 e-l	75.3 a-d
20	I	Nyeri	49.3 d-j	43.7 a-i	51.3 j-o	76.7 a-d
21	I	Kiambu	33.7 o	39.0 e-m	51.7 i-o	77.7 a-d
22	II	Taita	59.3 ab	43.3 a-j	46.4 m-p	77.7 a-d
23	II	Meru	33.7 o	29.7 h	48.3 p	65.0 cd
24	I	Machakos	42.3 k-n	33.3 lmn	56.3 f-m	65.3 bcd
Mbalaria	II	Migori	50.7 c-h	42.3 c-k	52.0 h-o	91.0 ab
26	II	Migori	41.7 k-n	47.7 a-d	49.0 j-p	91.7 a
27	II	Kwale	45.9 g-l	44.0 a-h	65.7 c-h	81.7 a-d
28	I	Kisii	42.7 j-m	32.0 mn	45.4 nop	84.3 a-d
SEQ 1001	II	CIAT	64.0 a	40.0 d-m	66.1 d-j	75.0 a-d
SEQ 1004	II	CIAT	50.3 c-i	49.8 abc	67.0 c-g	76.3 a-d
SEQ 1008	II	CIAT	51.6c-g	40.0 d-m	60.7 e-l	82.7 a-d
SEQ 1012	II	CIAT	52.4 c-f	49.7 abc	65.5 c-h	67.3 a-d
SEQ 1014	II	CIAT	50.3 c-i	45.7 a-f	55.3 f-n	74.3 a-d
34	II	Kiambu	46.0 f-l	42.3 c-k	49.0 p	63.3 d
Ulonzo	II	Kitui	45.3 g-e	45.7 a-f	78 abc	75.7 a-d
White Haricot	II	Taita	35.7 no	35.7 i-n	69.0 b-f	84.3 a-d
Mean			45.3	41.6	57.8	75.3
S.E			2.9	3.4	5.7	4.8
CV (%)			13.5	9.9	12.1	7.7

Note: Growth habit, I = determinate, II = indeterminate.
 Stress conditions, WS = water stress, NS = not stressed (irrigated).
 Means followed by the same letter are not significantly different at $p < .05$ (DMRT).

generally lower under the WST compared to the NST treatment. At both monitoring occasions under WST, relatively rapid taproot length and dry weight accumulation were recorded in genotypes 2 (Ex-Kitui), 8 (Ex-Kirinyaga), KAT B1, KAT B9, Ulonzo, and GLP x 92, while slow growth values were observed in genotypes Okuodo, 3 (Ex-Kisii), 22 (Ex-Taita), 28 (Ex-Kisii), and 34 (Ex-Kiambu). CIAT genotypes generally had higher root-growth values compared to the local collections during the second monitoring occasion (36 DAE) under both watering regimes. In a previous study, the genotypes that had higher root-growth values under water stress also had higher values for plant water status (RWC and LWP).

Table 2. Means of Root Dry Weight for Thirty-Six Dry-Bean Genotypes at Kiboko

Genotype	Root dry weigh (grams per plant)			
	15 Days after emergence		36 Days after emergence	
	WST	NST	WST	NST
1	0.11 no	0.52 bc	0.71 d-j	1.56 b-g
2	0.21 f-j	0.38 h-k	1.14 a	1.95 a
3	0.25 efg	0.32 e-r	0.49 k-n	1.56 b-g
4	0.21 f-j	0.35 k-p	0.56 j-n	1.36 d-k
5	0.18 h-m	0.41 g-j	0.80 c-g	1.07 i-o
6	0.15 j-n	0.32 mx	0.55 j-n	1.00 j-o
7	0.14 lmn	0.35 k-p	0.44 mm	0.98 j-o
8	0.58a	1.12 a	0.94 bc	1.99 a
9	0.14 l-o	0.43 e-i	0.77 c-h	1.23 g-n
10	0.26 ef	0.46 d-g	0.63 g-k	1.03 i-o
11	0.12 mno	0.41 f-j	0.56 i-n	0.93 l-o
Kat B9	0.51 b	0.56 b	0.80 c-g	1.95 ab
GLP x 92	0.54 ab	0.43 e-i	0.74 d-i	1.39 d-i
GLP 1004	0.23 e-h	0.35 k-p	0.71 d-j	1.27 f-m
Okuodo	0.16 j-n	0.29 pqr	0.44 mn	0.94 k-o
16	0.33 cd	0.30 n-r	0.56 i-n	1.63 a-g
Kat B1	0.29 de	0.45 e-h	0.82 c-f	1.30 f-m
GLP 2	0.20 f-k	0.38 i-m	0.77 c-h	1.52 c-h
19	0.17 h-m	0.31 n-r	0.44 lmn	1.10 h-o
20	0.16 i-n	0.51 bed	0.64 f-k	0.78 o
21	0.18 h-m	0.47 c-f	0.62 h-l	1.32 e-m
22	0.17 i-m	0.33 l-q	0.45 lmn	1.32 e-m
23	0.08 o	0.20 s	0.25 o	0.81 no
24	0.17 h-m	0.29 o-	0.58 i-m	0.91 mno
Mbalaria	0.22 f-i	0.41 g-j	0.84 cde	1.72 a-e
26	0.19 g-l	0.40 g-j	0.44 mn	1.40 c-i
27	0.21 f-j	0.43 e-i	0.66 e-k	1.24 g-m
28	0.21 f-j	0.30 n-r	0.66 f-k	1.65 a-g
SEQ 1001	0.21 f-j	0.52 bc	1.05 ab	1.34 e-l
SEQ 1004	0.21 f-j	0.26 r	1.06	1.39 d-i
SEQ 1008	0.14 k-n	0.48 cde	0.86 cd	1.68 a-f
SEQ 1012	0.33 cd	0.64 a	0.94 bc	1.81 abc
SEQ 1014	0.35 c	0.48 cde	0.78 c-h	1.45 c-i
34	0.33 cd	0.35 j-o	0.40 n	1.04 i-o
Ulonzo	0.59 a	0.36 j-n	0.68 e-j	1.33 e-l
White Haricot	0.15 k-n	47.35	0.61 h-m	1.04 i-o
Mean	0.23	0.4	0.69	1.33
S.E	0.03	0.03	0.18	0.17
CV (%)	12.3	8.3	22.4	15.4

Note: Means followed by the same letter are not significantly different at $p < .05$ (DMRT).

DISCUSSION

Results from this study showed consistent genotypic differences in the response of root growth to water stress. This variation may be useful in identifying genotypes for use in crossing programmes. The genotypes avoided water stress by developing a large, deep root system that efficiently extracted soil water at a lower soil profile, as evidenced by a greater increase in taproot length rather than root density as the season progressed, particularly in the nonstress treatment. During the early stages of water deficits, the plants responded by increasing their supply of stored moisture in the leaves to meet evaporative demand.

This study showed that at the seedling stage (15 days after emergence) under water stress, taproot length increased faster relative to the root dry weight. The reduction of the taproot length under the nonstress

condition could be attributed to a need for rapid root penetration rather than root density during the early growth stages. Another possibility for the reduction in taproot length under the nonstress treatment could be due to poor root aeration, arising from the soil being saturated with water, which reduces the oxygen supply due to low solubility and the slow rate of oxygen diffusion in water (Kramer, 1983). However, as the season progressed, the increase in taproot length and root dry weight was reduced under water stress. These results appear to show that rapid taproot growth in the early growth stage is desirable under water stress and may be useful in conferring tolerance to root rot, as in the case of GLP x 92, in areas where it is prevalent. Runkulatile et al. (1993) reported that bean varieties that are adapted to low rainfall areas, for example, Ulonzo and GLP x 92, had faster downward rooting ability compared to those adapted to higher rainfall areas. These observations agree with the findings of this study. Similar observations have also been reported in other drought-resistant pulses, for example, in cultivars of French beans (Sangakkara et al., 1996), field beans, and field peas (Grzesiak et al., 1997). This adaptation mechanism permits plants to maintain high plant water status by maintaining water absorption from lower soil profiles.

Compared to the genotypes of determinate growth habit (type I), the genotypes with an indeterminate growth habit (type II) had well-developed root growth, which may have maintained water uptake from the lower soil profile.

The results of this study suggest that rapid root growth is a desirable trait that may be included in a bean-breeding programme for development of cultivars adapted to environments with water stress. Longer roots explore the soil profile better, hence maintaining a balance between transpiration demand and water absorption.

A superior genotype in this respect could perhaps be developed for semi-arid areas of eastern Kenya by inter-crossing these genotypes. For example, the early-maturing varieties could be inter-crossed with those genotypes that have well-developed root growth under conditions of soil water deficits. This could fortify drought escape arising from earliness with other mechanisms of drought resistance, thereby reducing the risk of crop failure where rainfall is inadequate and erratic, a common feature in the semi-arid areas.

These inherent mechanisms of adaptation to drought stress (earliness and maintenance of high plant water status) may be enhanced by using improved cultural and agronomic practices that reduce the onset of internal plant water stress, rate of progression of water deficits in the soil and the severity and duration of drought. These practices include plant spacing and practices to conserve soil moisture, such as terracing, ridging of furrows before planting, and mulching.

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SESSION 3
PARTICIPATORY RESEARCH AND DEVELOPMENT

PARTICIPATORY IPM DEVELOPMENT AND EXTENSION: THE CASE OF BEAN FOLIAGE BEETLES IN HAI, NORTHERN TANZANIA

J. K. O. Ampofo, U. Hollenweger, S. M. Massomo, and E. Ulicky

ABSTRACT

Research and development activities focused on integrated pest management (IPM) were conducted in two farming communities in northern Tanzania (Makiba Division and Masama Division) using participatory approaches. In Makiba, research involved on-farm testing of new technologies for managing bean stem maggot (BSM). In Malama, CIAT was invited to help farmers solve some 'unusual' pest problems in their fields. Participatory processes were used in problem diagnosis, identification, and selection of possible solutions for evaluation. Participating farmers selected management strategies that were most compatible with their production circumstances. The community at large was made aware of the technologies through farmer-organised field days and farmer-to-farmer extension activities, which resulted in several farmer research groups that could work together to develop solutions to their production problems. In Masama, the bean foliage beetle (BFB) was identified through participatory surveys, problem diagnosis, and monitoring of pest biology and ecology. The ensuing IPM technology focussed on cultural strategies, and the farmers observed that a community approach was a good way to solve the problem as the pest could fly from one field to another. In both cases the participatory approach boosted farmers' confidence and enabled them to diagnose and identify solutions to problems in other crops, as well as sharing the acquired knowledge freely with others in their communities.

RÉSUMÉ

Des activités de Recherche & Développement axées sur la lutte intégrée contre les ravageurs s'appuyant sur la recherche participative ont été réalisées dans deux communautés agricoles situées au nord de la Tanzanie (Makiba et Masama). À Makiba, la recherche comprenait des essais de technologies nouvelles en situation réelle portant sur la lutte intégrée contre la mouche du haricot. À Malama, le CIAT était invité à aider les agriculteurs à résoudre quelques problèmes « inhabituels » causés par les ravageurs dans leurs champs. Le processus participatif a été utilisé dans la détermination du problème, l'identification et la sélection de solutions possibles. Les agriculteurs participants ont choisi les stratégies de gestion les mieux compatibles avec leurs conditions de production. Des journées sur le terrain organisées par les agriculteurs et des activités de vulgarisation de cultivateur à cultivateur avaient permis de sensibiliser l'ensemble de la communauté aux nouvelles technologies et avaient également conduit à la création de plusieurs groupes de recherche d'agriculteurs sachant élaborer en coopération des solutions à leurs problèmes de production. À Masama, la chrysomèle du haricot avait été identifiée au moyen d'un processus participatif d'études, du diagnostic du problème et de la surveillance de la biologie et de l'écologie des ravageurs. La technologie de la lutte intégrée ainsi élaborée était axée sur des stratégies de culture. Les cultivateurs ont remarqué qu'une approche fondée sur la communauté était une bonne façon de résoudre les problèmes étant donné que les insectes ravageurs peuvent voler d'un champ à un autre. Dans les deux cas, l'approche a renforcé la confiance des agriculteurs et leur a permis de déterminer et d'identifier des solutions pour des problèmes concernant d'autres cultures ainsi que de partager librement les connaissances acquises avec ceux faisant partie de leurs communautés.

Key words: IPM, bean foliage beetles, *Ootheca* spp., participatory technology development, extension system, technology dissemination, local/indigenous technical knowledge.

INTRODUCTION

Technologically sound and effective integrated pest management (IPM) strategies are often not adopted because farmers' production circumstances are frequently not well understood, or sometimes neglected in the generation and packaging of technologies. This is largely due to the fact that smallholder agriculture has

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often been considered primitive on the assumption that yields could be improved only by addressing deficiencies through the introduction of external inputs. Smallholder farmers, however, operate in complex, diverse, and risk-prone environments. Fixed prescriptions such as IPM packages do not work in such circumstances, since site-specific agro-ecological and socio-economic conditions often determine what is best at one place (Van Huis, 1997). To improve upon this, several concepts involving farmers in technology generation and diffusion have been proposed and tried. The generation of IPM technology is moving from research-station trials and subsequent transfer of results by the extension system to different levels of farmer participation to ensure greater suitability of the technology to farmers' production circumstances.

Here, we describe participatory approaches used to develop and disseminate IPM strategies for bean foliage beetles (BFB) (*Oothea* spp., Coleoptera: Chrysomelidae) in farming communities in the Hai District, northern Tanzania. The projects were initiated on invitation from the Hai District Extension Office to assist village communities in addressing some of their production constraints. The projects were conducted through community-learning activities.

NATURAL CONDITIONS, FARMING SYSTEM, AND SOCIO-ECONOMIC CHARACTERISTICS

The initial community learning site in the Hai District was Boma Ng'ombe in the Masama Division on the Sanya Plain (ca. 950 m altitude), which lies between Mt. Meru and Mt. Kilimanjaro. Rainfall records from the nearby Kilimanjaro Airport suggests an erratic bimodal rainfall with peaks in April-May (140 mm) and November-December (40 mm). The soils are shallow, stony, and weakly developed (lithosols) (JKADP, 1977; Lundgren, 1978), and irrigation water is limited to a few areas only. A mixture of ethnic groups, dominated by the Wachagga, populates the area. The population density is currently low (about 50 persons per sq. km) but increasing with immigrants from the uplands. The main occupation is crop and livestock farming, with maize, beans, and horticultural crops, such as tomatoes, carrots, and cabbages and sunflower, as the main crops. The principal growing season is March-June. The area lies along the main Moshi-Arusha highway and production is market driven and directed to the two major towns, Moshi and Arusha.

Aminu-Kano et al. (1992), in a participatory rural appraisal covering the Masama Division, observed that the farmers did not cite any problems associated with bean production. At that time beans constituted a minor crop in their production system. In recent years, however, farmers have come to consider beans as a more profitable crop and grow it as a monocrop season after season. Crop rotation is poorly practised. Several problems associated with continuous cropping of the same species have emerged as a result.

PROBLEM IDENTIFICATION

During the long rainy season of 1997, the Hai District Commissioner, Mr. Raymond Mushi, requested help from CIAT and the Selian Research Station to address a problem that was affecting bean crops in smallholder fields. Because of our previous experience with farming communities in Mbuguni Ward (CIAT 1998), the research team decided to adopt a participatory technology development (PTD) approach. During a preliminary survey, the research team went with extensionists to sample the fields in the affected areas and discussed cropping history with the farmers in order to diagnose the problem. The farmers showed us plants with the symptoms they were complaining about: stunted plants with yellowish leaves and premature senescence. Researchers uprooted plants showing these symptoms and examined them. In almost all symptomatic plants, there were larvae on the roots or in the soil where they were growing. Some lateral roots had been pruned off, the nodules had collapsed, and the epidermis on the attached roots had been lacerated. Healthy plants were free of larvae and damage. We (farmers, extensionists, and researchers) concluded tentatively that the larvae were causing the symptoms we were seeing on the plants. The researchers identified the larvae as *Oothea* (BFB).

After the preliminary survey by researchers and the district extension officers (led by Dr. Edward Ulicky), the farmers were invited to a plenary meeting of representatives of all the affected communities to share the results of the initial survey and develop studies to better understand the pest, its spread and ecology and to develop research activities and solutions to address it (table 1).

Table 1. Summary of Farmer Group Discussion, Research Activities, and R&D Needs as Identified and Agreed on by the Farmers, Extension Agents, and Researchers

Phase	Discussion points	Activities	Research & development needs
1	Discussion on cropping history of sampling sites	<ul style="list-style-type: none"> • Problem identification and analysis • Field sampling of plants, roots, and soil for cause of above-ground symptoms 	<ul style="list-style-type: none"> • Pest identification • Life cycle and ecology • Pest distribution
2	Results from research in Phase 1 Potential control strategies	Field visits to monitor on-going research activities.	Evaluation of potential control strategies <ul style="list-style-type: none"> • Post-harvest tillage • Crop rotation • Host plant resistance • Insecticide application • Post-harvest flooding • Delayed sowing of beans • Insecticide (neem) application
3	General research results Strategies for area-wide management	Request to local administration to enforce community adoption of area-wide management strategies	Extension of management strategies with posters, bulletins, and farmer-to-farmer activities

STUDIES OF THE PEST

After the initial investigation, the research team confirmed the problem as bean foliage beetle (BFB) larvae attacking bean plant roots and causing premature senescence. However, the farmers and some extension officers could not relate the adult BFB and its damage (chewing holes in leaves and causing defoliation) to the larval damage (root feeding, nodule poaching, and the resultant premature senescence). The local belief was that ‘the BFB come with the rains but heavy rain effectively drowns them.’ Because of this, the only solution they could suggest was rain. We agreed to do a participatory study of the biology and ecology of the pest by following through the development of the larvae until they turned to adults and continued through oviposition and the different stages again (i.e., a full life cycle of the pest) (table 2 and figure 1). We did this through a sequential sampling of affected plots and mapping out the distribution in the area as well as distribution in relation to depth of soil. Changes in the life stages of the pest were also monitored until adults were formed. The pest was widely distributed, but the severity of its damage varied. Over 80% of the subterranean forms were within the top 20 cm of the soil and the mean population was about 100 insects/m². The study helped all participants to understand the BFB life cycle and ecology better, which enabled them to identify potential control methods (see table 1, phase 2) and participate actively in generating strategies for BFB management.

Table 2. Summary of *Ootheca* Life Cycle in Relation to Bean Planting Cycle at Hai, Northern Tanzania (see also figure 1)

Period	Developmental activity
March/April	Adult emergence in synchrony with rains and planting of beans. Adults cause defoliation to bean seedlings. They mate and deposit eggs in soil near bean plants. Emerging larvae feed on bean roots, removing secondary roots and causing injury to primary roots. They also poach nodules.
May/June	Larval damage to rooting system disturbs nutrient flow from the soil and causes plants to senesce prematurely and bear few pods, each with few seeds.
July	Beans are harvested but <i>Ootheca</i> is left in the soil in different stages of development. Populations may exceed 100/m ² . Land is left fallow and <i>Ootheca</i> population development continues.
August	Pupation starts in the soil.
September	Adults are formed but remain in soil and undergo diapause.
October to March/April	Adults remain in diapause until the beginning of the rains, when they emerge to attack newly emerged beans.

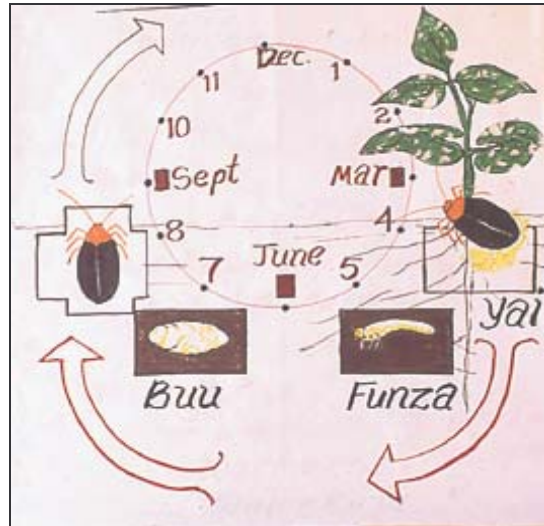


Figure 1. Life cycle of bean foliage beetle (*Yai* = eggs [adult laying eggs in soil]; *Funza* = larva [feeding on roots in soil]; *Buu* = pupa [developing in soil])

Strategies included the following (table 3):

- post-harvest tillage: to expose the immature stages in the soil
- crop rotation: the farmers observed that large-scale growers who often rotated beans with other crops did not have the problem
- delayed sowing of beans: farmers observed that the problem was more acute in the early sown crop
- application of pesticides such as neem, etc.

Table 3. Summary of Farmer Group Discussions on Possible Control Strategies

Strategy	Views for	Views against:
Post-harvest tillage	BFB is no problem in commercial production systems where this is practised	Hai soils are rocky and post-harvest tillage may be difficult
Delayed planting	May be useful in monocropped beans	Rainfall distribution may not allow crop to grow to full maturity
Crop rotation	A potentially good strategy	May not be practical where fields are small
Insecticide application	<ul style="list-style-type: none"> • Research needed on use of neem • Research needed on insecticides that can be applied at planting Use of insecticides requires a collective approach so all farms will be sprayed simultaneously to avoid migration to other fields	
Biological control	<ul style="list-style-type: none"> • No knowledge available • Research needed to identify possible natural enemies 	

These strategies were tried under farmer/researcher-designed and farmer-managed conditions. The results are summarised in figures 2–5, below.

EVALUATION OF POTENTIAL CONTROL STRATEGIES

Findings from these experiments were discussed during evaluation meetings with everyone involved, and all contributed to the conclusions and recommendations. The following is a short description of the results of the strategies tested.

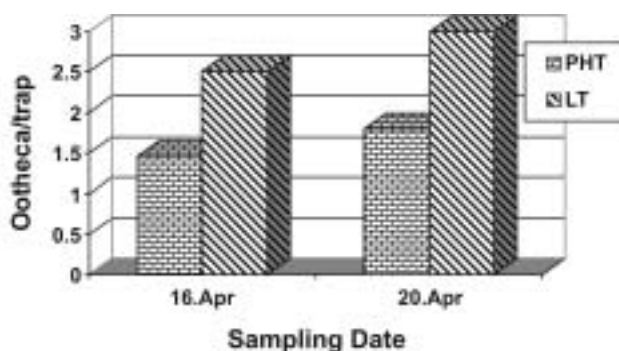


Figure 2. Effect of post-harvest (PHT) and late tillage (LT) on BFB populations in farmers' fields at Hai

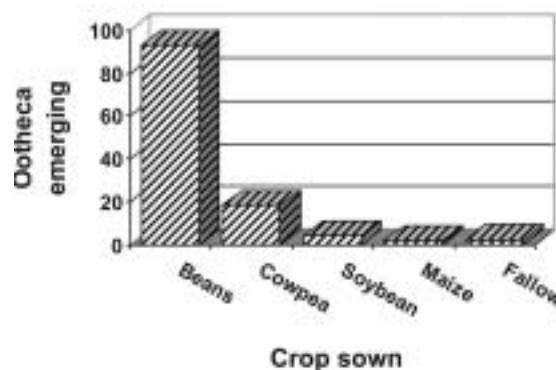


Figure 3. Crop effect on BFB emergence pattern

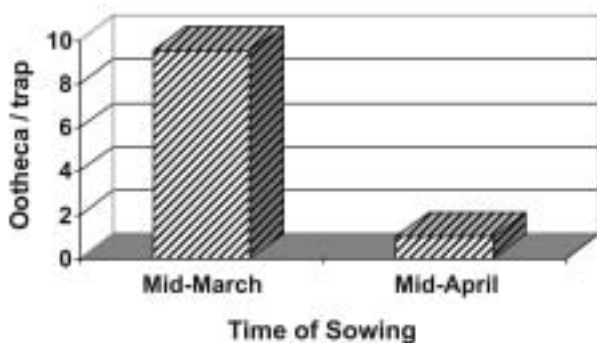


Figure 4. Effect of sowing time on BFB emergence pattern

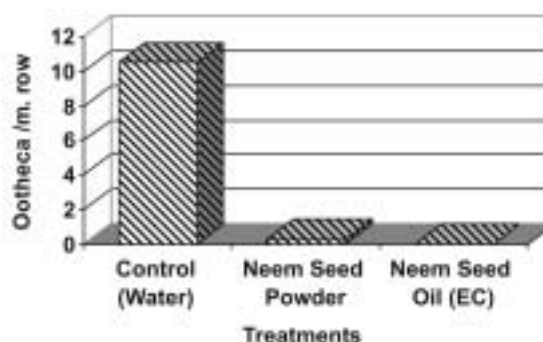


Figure 5. Effect of neem foliar sprays on adult BFB infestation

Zero tillage and post-harvest tillage

Both practices reduced pest emergence from the soil and subsequent crop damage. We all deduced that post-harvest tillage exposed the subterranean form of the insect to the elements and predators and reduced the residual population. Tillage just before planting facilitated the emergence of the pest from the soil, compared to zero tillage (figure 2). We reached the following recommendation, with general consensus: because of the pest's ability to fly to other plots, these treatments would be ineffective when practised in isolation.

Crop rotation

Maize, beans, cowpeas, and soybeans were planted after beans in a plot known to have a high level of residual BFB infestation. There was BFB emergence in response to the germinating beans and cowpeas but not to the maize and soybeans (non-hosts) (figure 3). Mr Ringo, one of the farmers who had been doing experimentation on his own, had rotated his bean field with sunflowers and observed the same effect: that sunflowers suppressed the emergence of BFB, compared with beans. This was a clear indication that growing beans after beans in the same plot permitted the continuous development of BFB and its population build-up and that rotation with non-hosts would interrupt the cycle and reduce the pest population.

Delayed sowing

Beans sown late (mid-April) emerged when BFB populations were low and were attacked less, compared to the March-sown crop (figure 4).

Neem sprays

Foliar application of neem seed oil and neem seed powder protected the bean plants from adult infestation for periods of more than five days per application (figure 5).

SUMMARY OF THE RESEARCH AND TECHNOLOGY-DEVELOPMENT PROCESS

As summarised in table 1, we had several phases of discussion and participatory research activities. At the end of each phase, we discussed the findings in an open plenary meeting, made inferences from the results,

and developed further activities. Experiments conducted were developed mostly through discussions with farmers and extension officers. Some farmers (e.g., Mr. Ringo) did their own research, which turned out to be complementary to the group research, and they shared the results with the larger group during the plenary meetings. Further experiments were based on the results of the previous ones. We developed control strategies collectively, as listed in table 3.

The farmers observed that while the methods we had developed worked well, they were unlikely to be effective if applied individually on small plots because the pest could fly from one field into another. In fact, some farmers who had practised post-harvest tillage (and still had their plots attacked) accused others who had not for ‘letting their insects invade other farmers’ fields’. In a plenary meeting, the farmers appealed to the local administration to pass a by-law to enforce area-wide adoption of the IPM strategies. We all agreed in that meeting that the technologies should be extended to other communities beyond the Masama Division.

EXTENSION-LED SCALING-UP OF PARTICIPATORY IPM DISSEMINATION

After developing the research and management strategy, all agreed that the results should be spread to the whole district. The District Extension Service, headed by Dr. Edward Ulicky, called a meeting of Hai village extension officers (VEOs) and farmer representatives from the ‘hot-spot’ areas. The collaborators from the first phase of the project in Boma Ng’ombe, especially participating farmers, described the activities they had undertaken to solve the BFB problem. We reviewed the results and the methods used to achieve them (table 3). We then discussed available options that had not been tested. One of the strategies mentioned by farmers was fermented cow urine used as foliar application. We then discussed which strategies were feasible in different villages. Crop rotation was not considered possible with their small land holdings. Planting date and application of neem oil, neem powder, and cow urine were selected as common strategies in all villages. We then had a brainstorming exercise on potential pathways for disseminating the BFB management strategies. The extension officer and some farmers from each village discussed possibilities, considered their resources and the opportunities available to them, and identified the dissemination strategies that best fit their circumstances.

The dissemination pathways selected by different villages were (in order of rank): (1) on-farm demonstrations, (2) demonstrations in schools, (3) training through farmer research groups, (4) distribution of extension information leaflets about the problem and its management, and (5) awareness-creating seminars and field tours. Each group went back to its constituency, and the VEO used existing extension groups to form farmer research groups (FRGs). Their objective was to effect the dissemination of management strategies suitable to their respective environments by means of promoting local experimentation. At the local level, the FRG reviewed the management and dissemination options suggested by the participants of the meeting in Hai (the Hai-group), modified them as was appropriate, and added locally known treatments because of their limited access to some of the suggested treatments (like neem). The local treatments and the ones suggested by the Hai-group were investigated together. In some villages, cow urine was modified using a urine/faeces slurry (*mfori*) instead of urine, and ash and a soap/kerosene mixture were added as other treatments. In similar work in the Lushoto area (northeast Tanzania), the farmers opted to try some locally known plants, like *mhasha* (*Vernonia* spp.), *luli*, and *donondo*, but did not try cow urine, ash, or soap and kerosene. The groups installed learning plots in the different villages, which were managed by the FRG with VEO help and some advice from researchers. The groups received neem oil and powder from the researchers, but everything else the farmers provided themselves. Unfortunately, most of them failed because of the ‘la niña’ drought. The site at Sanya Juu survived and was used by all the nearby villages as their learning site.

The IPM strategies selected by the Hai-group for this site were planting time of beans to avoid peaks of BFB infestation, application of botanical pesticides (neem oil and neem powder) and fermented cow urine, and creating an awareness of the pest. The dissemination strategies were seminars, distribution of IPM extension leaflets, and field demonstrations of the management strategies. Mrs. Amanda Koola, the Sanya Juu VEO, and her group set up the demonstrations in farms where they would be seen by many within the community, in schools, and also in community training centres. In addition to the demonstration of the proposed technologies, the FRGs selected and tested their own traditional methods, which they felt might be appropriate. The traditional methods selected by the farmers were (1) fermented liquid effluent from the cow shed (a slurry of urine and feces), (2) kerosene and soap mixed with water, and (3) ashes. Figure 6 shows the performance of the different treatments, all of which worked better than the control. The effect of cow urine lasted longer and delayed re-infestation beyond five days.

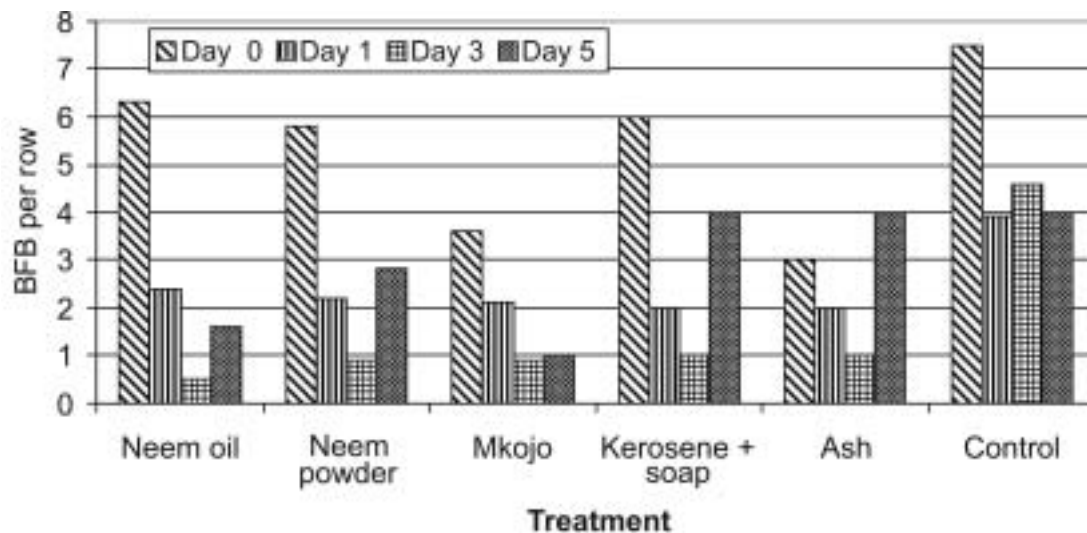


Figure 6. Performance of neem and other traditional treatments against BFB adults in farmers' fields

The VEOs used the demonstrations at schools and community training centres to train students about bean production, pest and disease identification, and IPM in general. At intervals the VEOs had field days and invited the general community to view, discuss, and appraise the demonstration through open discussions. In addition, the researchers developed a short questionnaire that was filled in by both participants and visitors. The field days were also conducted to make more people aware of the pest and opportunities for management, as well as making them aware of another approach to extension, i.e., through experimentation.

Ashes, neem oil, and fermented cow urine were the most preferred treatments for BFB control (figure 7). With regard to the dissemination process, farmers preferred (1) more seminars for creating awareness, (2) improving the extension system (empowering the extension service), (3) dissemination through the mass media to reach more farmers (figure 8). In addition, the non-participating farmers were strongly in favour of more demonstrations, while the participating farmers requested more IPM training to enable them to understand and manage other pests using participatory approaches. Large farmers (> 1 acre of beans) selected group training as their preferred option for IPM dissemination, while the small farmers preferred demonstrations (figure 9).

The District Extension Service organised a post-season monitoring and evaluation meeting, again inviting participating VEOs and farmers, as well as new ones. Together we discussed the results of the season and

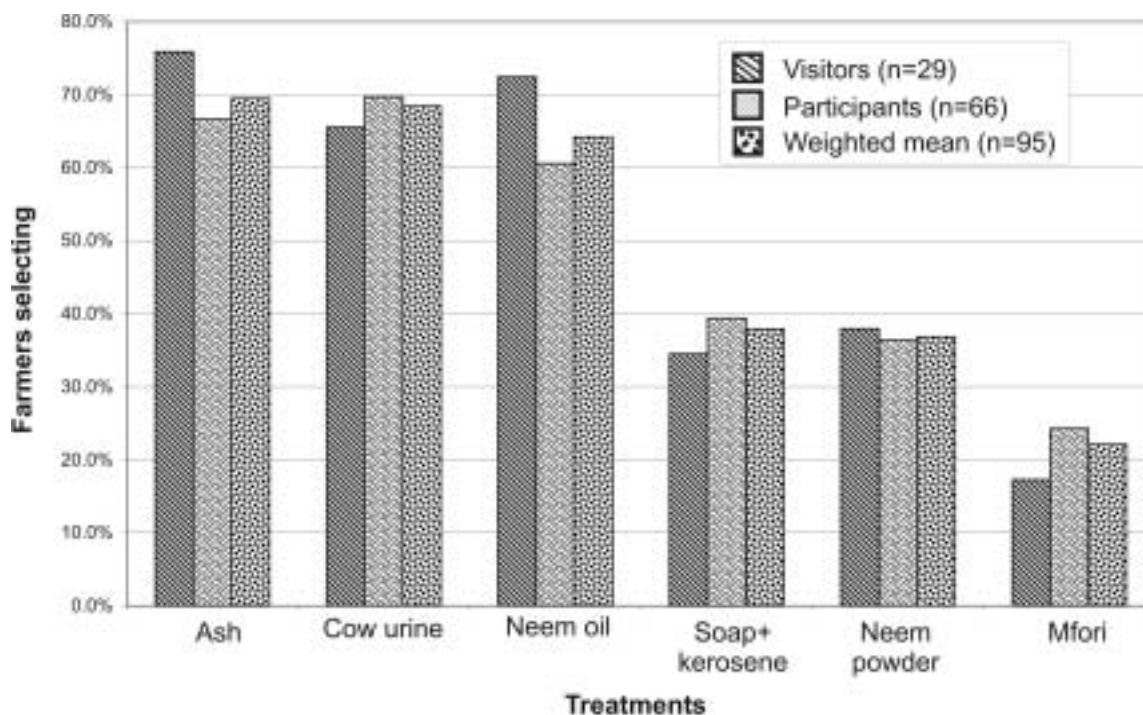


Figure 7. Preferences of FRG members and non-members for BFB management strategies

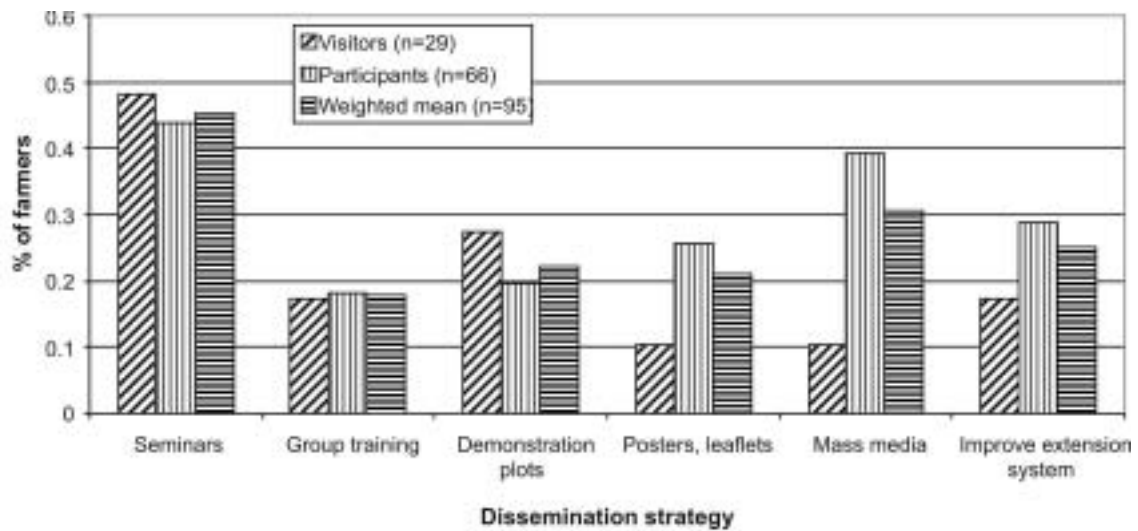


Figure 8. Selection of IPM dissemination channels by FRG membership

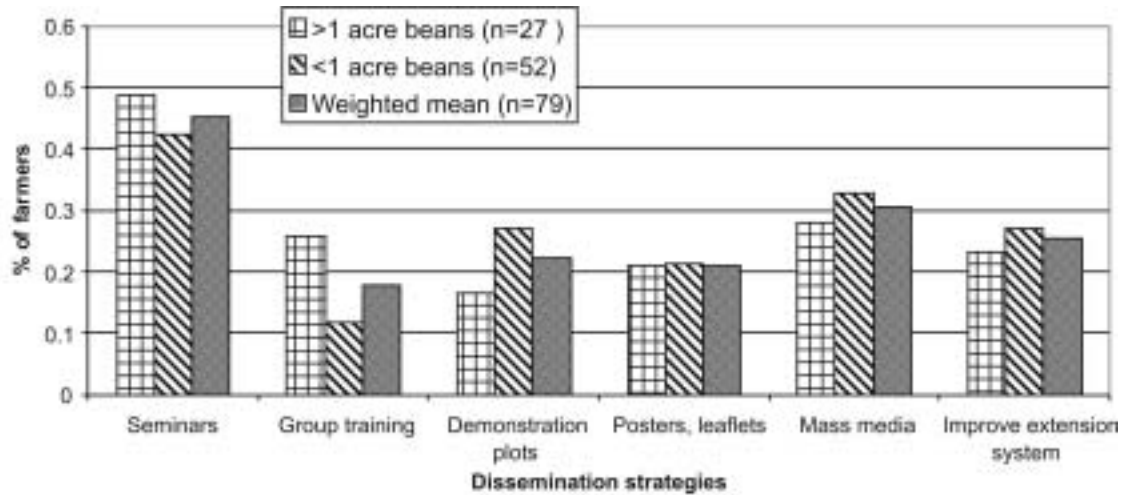


Figure 9. Selection of IPM dissemination channels by farm size

planned the way ahead. Concerning the dissemination of technologies, the farmers cautioned that multiple strategies should be used rather than a single one because different strategies target different categories of farmers. The VEOs lamented that it was difficult to go to farmers without ‘a new message’. Taking up the comments of the farmers that the extension system should be improved, all agreed that continued work on IPM in close collaboration with farmers and research would help the extensionists to improve their work. The approach of using groups, participatory discussions, and common learning plots was considered essential for success. In the discussion we identified other pest problems that should be tackled in the coming season. The same participatory approach was chosen, but there will be less direct research, as some pests have already been worked on in other districts in a similar way and we expect positive synergies between those experiences.

The exercise gave a boost to the District Extension Service, as they are able to reach more farmers with new technology to solve a problem limiting bean production in the area, and they know that continued support will help them to work on other problems. They are also convinced that the participatory approach contributed to the dissemination of BFB management strategies. There is now an increased demand from VEOs and farmers for IPM promotion to reach more farmers. The extension service and the farmers have initiated a radio program to discuss IPM strategies for bean and other crop pests. The program is aired on *Redio Sauti ya Injili*, a rural broadcasting house in Moshi reaching most parts of northern Tanzania. They have also started dissemination through songs and dances. Research and the District Extension Service have started to train more VEOs in the approach itself. This is done with two-day seminars, where extension officers, who participated in the research process but did not receive any other training, teach their colleagues on the approach. Researchers also teach part of the course on trial planning, data collection, and analysis. The District Extension Service continues to meet with some of the VEOs as follow-up.

Unfortunately, other VEOs need to try the approach without further help because of limited means for follow-up. Through this training, more extensionists have learned about the work, which has resulted in a better understanding of the importance of involving farmers and greater commitment to their work in general. This will help to institutionalise the approach at the grass-roots level of the extension system.

CIAT and the bean networks have adopted participatory research as one of the mainstream processes for technology generation and dissemination and have instituted the project, Participatory Research for Improved Agro-ecosystem Management (PRIAM). The purpose of this project is to develop and promote participatory research methodologies and community-based projects within national agricultural research institutes, government organisations, and NGOs for common use in improving soil, crop, tree, and disease and pest management. The project collaborates with several national programmes, commodity networks, and the African Highlands Eco-Regional Initiative (AHI).

In addition, PTD for IPM is being institutionalised in the bean networks through a DFID-sponsored project on IPM promotion for bean pests. We (CIAT and partners) have developed this project to target all areas with the *Oothea* problem. Currently, activities have been initiated in western Kenya, northern and southern Tanzania, and northern Malawi. This project helps to train extensionists and farmers who accept, adapt, and experiment with new technologies to better understand the PTD approach for sustainability, which will hopefully show an impact in the national research and extension systems.

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FARMER FIELD SCHOOLS AS A METHODOLOGY FOR DEVELOPMENT, DISSEMINATION, AND UTILISATION OF IMPROVED BEAN TECHNOLOGIES IN ISANGATI FIELD SITE, MBEYA DISTRICT, TANZANIA

M. M. Mkuchu, D. Kabungo, C. S. Madata, A. N. Mussei, and Ndomba

ABSTRACT

Farmer field schools (FFS) were tested as a methodology for the development, dissemination, and use of improved technologies in bean production and pest control among smallholder farmers in Tanzania. Two villages, Isuto and Mbawi, were selected in Isangati Division. The introduction of the FFS concept created enthusiasm among farmers, and farmer groups with more than 20 members were formed. The farmer groups selected the treatments during a planning meeting and established experimental plots. The study shows that FFS is participatory, with a bottom-up approach, emphasising collaboration between researchers, extensionists, and farmers. Training and planning meetings encouraged farmers, and they learned to keep records and do simple experiments. The diffusion rate of new technology in a community where the FFS approach is used has been noted to be high. However, participation of both female farmers and policymakers was noted to be low. Launching seminars and workshops on FFS to policymakers and initiating FFS for women's groups could improve the situation. The use of FFS in Tanzania and in other parts of the region is very relevant and has a high chance of being adopted because of a high ratio of farmers to extension staff, insufficient funds to support extension services, lack of farmer participation in technology development, and the fact that most smallholder farmers live in rural areas where the use of mass media is limited.

RÉSUMÉ

Les formations FFS (farmer field schools ou stages sur le terrain pour agriculteurs) ont été mises à l'essai en vue de faciliter parmi les petits exploitants agricoles tanzaniens le développement, la diffusion et l'utilisation de technologies améliorées dans le cadre de la production du haricot et de la lutte contre les ravageurs. Deux villages, Isuto et Mbawi, ont été choisis dans le district d'Isangati. L'introduction des formations FFS a suscité l'enthousiasme des agriculteurs et des groupes composés de plus de 20 exploitants ont été formés. Au cours d'une réunion de planification, les groupes d'exploitants ont sélectionné les traitements et mis en place des parcelles d'expérimentation. L'étude réalisée a montré que l'approche FFS est une approche participative partant de la base, intensifiant la collaboration entre chercheurs, vulgarisateurs et exploitants. La formation et les réunions de planification ont encouragé les exploitants qui ont appris à tenir des registres et à faire des essais simples. On a noté un taux de diffusion élevé des nouvelles technologies dans les collectivités où était appliquée l'approche FFS, en dépit d'une faible participation des agricultrices et des décideurs. Des séminaires et des ateliers sur les FFS destinés aux décideurs et la mise en place de FFS pour des groupes de femmes pourraient contribuer à améliorer cette situation. Les formations FFS en Tanzanie et dans d'autres parties de la région sont très utiles et ont de grandes chances d'être adoptées du fait du faible effectif de personnel de vulgarisation par rapport au nombre d'agriculteurs, du financement trop restreint des services de vulgarisation, de la participation insuffisante des exploitants dans le développement des technologies et du fait de la quasi absence de mass médias dans les régions rurales où vivent les petits exploitants agricoles.

INTRODUCTION

Agriculture forms the backbone of the Tanzanian economy, with about 85% of the population living in rural areas where the main occupation is farming. Crop output remains very low and highly variable, resulting in low and unevenly distributed income. The performance of this sector determines the economic situation of

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both the urban population and rural households. Thus, increases in agricultural productivity can reduce the problem of rural poverty and food shortages and increase agriculture exports. Appropriate agricultural technologies, using appropriate methodologies, must therefore be generated and disseminated to farmers.

In Tanzania, agricultural improvement is being done through crop research, among other measures, including research on beans (*Phaseolus vulgaris*). Many high-yielding and disease-resistant crop varieties have been developed and released to farmers, together with recommended agronomic packages. For instance, the bean varieties released include Uyole 84, Kabanima, Uyole 94, Uyole 96, Ilomba, and Uyole 90. The average yield potential of these bean varieties has been found to range between 1500 kg/ha to 2000 kg/ha.

In order to increase crop yields, new crop technologies have to reach and be used and maintained by the target group (growers). Development projects (e.g., ADP, MOP, IFAD, and ILCA), research organisations, and extension agencies in Tanzania have been involved in developing and disseminating improved crop technologies to farmers using various extension methodologies before and after independence, with an emphasis on promoting modern agriculture. Farmers were urged to switch to cash crops, to grow crops in pure stands, and to adopt new high-yielding varieties, together with the use of fertilisers, pesticides, and irrigation. In many cases, the technological packages that were supposed to generate agricultural growth failed to deliver the expected benefits of high productivity, better food security, and high living standards for the people of Tanzania.

In the 1980s, the World Bank promoted the Training and Visit (T&V) system approach in Tanzania to replace the farming system research (FSR) approach. Spore (1997) reported that T&V is based on developing competent extension agents at the regional or district level, where they receive regular training and briefing before going out to interact with target farmers. The system uses leader farmers and demonstration farms, but it was found to be expensive and not participatory.

The World Bank Supervision Mission visited the Tanzania Ministry of Agriculture in December 1997 and recommended testing the farmer field school (FFS) approach as an alternative method of delivering extension messages and improving linkages and the sustainability of extension programmes. The FFS concept originated in Asia, and it is an example of group extension methods that save costs and evolve into truly participatory analysis, planning, and execution of projects, addressing those areas seen to be priorities by the community.

In the 1980s, two FFS projects, funded by FARMESA, were initiated in Tanzania. One is a maize project based at Gairo Mlali field site for semi-arid areas in the Morogoro region and the other is a bean project based at the Isangati Division field site for highland areas in the Mbeya region.

This paper discusses farmer field schools as a potential methodology for developing and transferring appropriate technologies to smallholder farmers in the Isangati Division field site. The field technologies used in testing this approach were the introduction of improved bean varieties and production packages, and integrated pest management (IPM) for beans.

BACKGROUND TO THE STUDY

Problem statement

Participatory rural appraisal (PRA) identified the *Phaseolus* bean as one of the most important food and cash crops in the Isangati Division (Mussei et al., 1998). However, its productivity was low, ranging from 125 kg/ha to 750 kg/ha because of a lack of technological knowledge on improved bean technologies, including field pests (aphids, pod borers, and bean stem maggots) and post-harvest pests (bruchids), which accounted for a 50% yield loss in beans and affected about 85% of the farmers in the target area. The PRA results also indicated that inadequate extension services resulted in a lack of dissemination of pest-control technologies to farmers. It has been documented that there are only seven village extension workers to serve 27 villages.

In order to overcome these problems, FFS was introduced. The literature indicates that this approach has been successfully employed elsewhere, where farmer circumstances are similar to the field site.

Brief description of the study area

The study was carried out in the Isangati Division field site, which is located in the southern part of Mbeya rural district, in the Mbeya region. Two villages were selected: Isuto (which lies in the lowland or coffee zone, below an altitude of 1900 m) and Mbawi (which is in the highland or pyrethrum zone, above 1900 m).

Temperature are higher in the coffee zone than in the pyrethrum zone. The range of average rainfall for the coffee zone is 750mm to 1200mm per annum and that for the pyrethrum zone is 900mm to 1400mm per annum. Soils are moderately fertile in the pyrethrum zone, while those in the coffee zone are low. Farmers in the pyrethrum zone grow maize, beans, potatoes, wheat, and pyrethrum without fertilisers. In the coffee zone, farmers grow maize, beans, finger millet, and coffee, and apply fertilisers to coffee only. Household income for the farmers in the highland zone is low compared to those in the lowland zone because of differences in the cash crops. Farmers sell their produce through local markets, which are held once a week in each village. There are no organised financial institutions. There is at least one primary school in each village.

Objectives of the study

The study objectives were to develop, utilise, and disseminate improved technologies on controlling bean pests and improving bean production using FFS as a methodology.

Objectives of the case study intervention

- to promote the use of botanical insecticides in controlling aphids, pod borers, and bruchids
- to assess and improve existing storage management practices
- to train farmers in both integrated insect pest management and bean production technologies

FIELD METHOD FOLLOWED

The farmer field school was used as an extension method to verify and transfer appropriate improved bean technologies to small bean growers in the Isangati Division field site. The main focus was on development, use, and dissemination of improved technologies on pest control and production. Several steps were involved, as listed below.

Participatory rural appraisal (PRA)

Prior to initiation of FFS activities at Mbawi and Isuto, a two-day PRA was held in each village to identify and prioritise the problems and needs of farmers.

Introduction of FFS concept to farmers and formation of farmer groups

After problem identification and analysis, a one-day meeting was held in each village in order to introduce the FFS concept to village members and form farmer groups, which were further divided into sub-groups of five to six farmers to simplify discussions during agro-ecosystem analysis.

Training workshop with farmers' groups

A one-day training workshop was held in each village to allow both farmers' groups and researchers to discuss farmers' experiences with bean production and researchers' experiences with improved bean technologies. Thirty farmers participated at Isuto and 25 Mbawi. Four research officers (an agronomist, breeder, entomologist, and socio-economist) facilitated the workshop along with one staff member from the area development programme (ADP) and one village extension officer (VEO). Topics included principles of seed multiplication, improved agronomic practices, control of insect pests (in both store and field), and socio-economic circumstances that affect the adoption of a new technology.

Planning meeting with farmers' groups

After the training workshops, a one-day planning meeting was held in each village to allow the members of the farmers' group to select treatments to test against conventional practices. They also made a working calendar for the FFS activities. Again, there were 30 farmers in Isuto and 25 in Mbawi who participated in the planning meeting, which was facilitated by the four researchers, ADP staff member, and VEO.

Establishment and management of demonstration and experimental plots

About half an acre of land was provided to the farmers' group in each village. At Mbawi, the land was provided by farmers, whereas at Isuto it was provided by the village government. The land was prepared over three days by group members, which involved land clearing, ploughing, and harrowing. The activities carried out in each village were seed multiplication, verification of botanical insecticides in aphid and pod

borer control, and verification of planting time for early-maturing bean varieties. Two activities originated from farmers during the training workshop: (1) in Mbawi village, investigation of the effects on yield of removing a growing tip on a semi-climbing bean plant and (2) in Isuto, cultural control of bean stem maggot. The specific methodology for each activity is indicated below:

- **Establishing planting time for early-maturing bean varieties.** In Isuto, two early-maturing bean varieties (Uyole 96 and Uyole 94) were evaluated in comparison with a local bean variety (Kablanketi). The bean varieties were planted with fertiliser on 1 and 15 March 2000 following farmers' practice. In Mbawi, Uyole 98, Kabanima, and Kablanketi were compared. The beans were planted with and without fertiliser on 15 and 30 March 2000 following farmers' practice, and on 15 April. A randomised complete-block design was used at both villages with four replications. Plot size was 5m by 5m. Spacing was 50cm between rows and 10cm within rows.
- **On-farm seed multiplication of early-maturing bean varieties.** Two improved bean varieties (Uyole 98 and Kabanima) and one local variety (Masusu) were selected by farmers and planted on 30 March 2000 in a demonstration plot at Mbawi. Farmers were trained on the principles of seed bean production and given good husbandry packages for bean production. Two improved varieties (Uyole 96 and Uyole 94) and a local variety (Kablanketi) were planted on 15 March in a demonstration plot at Isuto. Plot size was one-quarter acre. The recommended fertiliser rate was applied at planting for all the bean cultivars. Insect pest control was done as recommended. The fields were kept weed free.
- **Verification of botanical insecticide in aphid and pod borer control in bean fields.** Kabanima was planted in mid-March 2000 at Isuto, and Uyole 98 was planted in late March 2000 at Mbawi. Planting dates were set in order to catch high aphid and pod borer infestations in both villages. At Isuto, botanical insecticides (tephrosia and pyrethrum) and ashes were applied to the beans; those applied at Mbawi were tephrosia, pyrethrum, and kweme. All botanical insecticides were compared with the chemical insecticide Selecron. Effects were compared with infestations on an untreated plot.

A randomised complete-block design with four replications was used. Plot size was 4m by 4m, with 10cm within rows and 50cm between rows. A recommended rate of fertiliser (60kg P₂O₅ per ha and 30kg N/ha) was applied at planting. Selecron (30ml in 20 litres of water) was sprayed on beans within five days after emergence to control bean stem maggot. Botanical insecticides were applied only when aphid and pod borer infestations were observed on the plants.
- **Cultural control of bean stem maggot in bean fields.** Two bean varieties, Kabanima as a susceptible bean variety and Cinon as a cultivar resistant to bean stem maggot, were planted with and without fertiliser on 15 March at Isuto. Cultural control treatments included (1) untreated, (2) earthing up alone, (3) earthing up plus fertiliser, (4) fertiliser plus insecticide together with earthing up. A randomised complete-block design was used with four replications. Plot size was 4m by 4m. Spacing was 10cm within rows and 50cm between rows.
- **Study of effects of removing the growing tips of semi-climbing bean varieties on yield.** Two semi-climbing bean varieties, Uyole 96 (improved) and Masusu (local), were planted with and without fertiliser on 30 March at Mbawi. The growing tips in half of the plots were removed at the vegetative stage of the plants. Bean plants on the rest of the plots were left with growing tips. Observations were made on pod load, date to physiological maturity, seed size, and grain yield per plant.

Monitoring and evaluation of experimental and demonstration plots

The most important activities in the FFS approach were monitoring and evaluation of experimental and demonstration plots, which was done weekly by sub-groups, facilitated by researchers and extension officers. Ten plants were marked at various points in each plot. Participating farmers identified bean stem maggot, bean diseases, and aphids on the plants. They also observed weather conditions, stage of plant growth, differences in flowering dates and disease resistance among bean varieties, differences in insect population in relation to the types of insecticides applied, and differences in plant vigour and leaf colour in relation to planting dates and fertilisation.

After field observations, sub-group members, facilitated by scientists, analysed data and discussed the results. This entailed drawing the plant at its present state of growth and sun or clouds to symbolise weather conditions. Comparisons were made among treatments in regard to types and number of insects and types and intensity of bean diseases, and whether they would reduce bean yield was discussed. Each small group made conclusions on the status of their findings. After discussions, each sub-group presented its findings and

conclusions to the larger group, which criticised their results. Based on these discussions, a decision was made as a group about what measures should be taken in the experimental and demonstration plots.

Farmer field days and harvesting the experimental and demonstration plots

Farmer field days were conducted at the harvesting stage. All village members were invited. Preliminary discussions were held during the field tour in order to clarify what was observed. All experimental and demonstration plots were harvested after the farmer field days.

ACCOMPLISHMENTS/RESULTS

Introduction of farmer field school (FFS) and formation of farmers' groups

Fifty-two village members (10 female and 42 male) at Mbawi and 32 (8 female and 24 male) at Isuto attended the FFS introduction meeting. This poor attendance could be due to changes in the dates for the meetings in each village. The low number of females participating in the meeting could be due to the large number of field activities they had to attend to at that time. The introduction of the FFS concept created enthusiasm among farmers in both villages. Farmers formulated criteria for selecting members for the farmers' group, including (1) he/she should be a farmer who has grown beans for at least two years, (2) he/she should be willing to learn and later teach other farmers in the village after FFS activities are over, and (3) he/she should be highly accepted by the community. As a result, farmers' groups with common interests were formed in each village. The Mapambano farmers' group at Isuto had 30 members and the Mbenya farmers' group at Mbawi had 25 members.

Training and planning workshop

The training workshop enlightened members of the farmers' groups about improved bean varieties, improved agronomic practices (such as planting time, spacing, weeding, etc.), principles of bean seed production, and bean pest control in both store and field. This helped farmers in each group to select treatments to test against their conventional practices and, subsequently, to draw up a working calendar for the FFS activities. For example, farmers' group members at Mbawi decided to plant beans with and without fertilisers in order to evaluate the effects of fertilisation on bean production at various planting dates because farmers in Isangati Division do not apply fertilisers to most crops, and they selected Masusu and Kablanketi as local checks in their experimental or demonstration plots. The training also stimulated farmers to share their experiences on bean production with researchers. Farmers from both villages mentioned several botanicals they use as insecticides in bean fields and stores. These included tobacco, *ipasyapasya*, ashes, *kweme*, and finger millet husks, of which researchers were not aware. They also listed the names of local bean cultivars grown in their villages and the reasons for growing them. Masusu and Ntandabala are grown by farmers for their high-yielding and disease-resistant characteristics, while Kablanketi and Msafiri are grown because they are marketable. The selection of the field site was considered an important factor in Mbawi. Farmers insisted that the site of the land for bean production should always lie south-west of the undulating hills.

Monitoring and evaluation

Weekly monitoring and evaluation of experimental and demonstration plots encouraged farmers to build up a spirit of learning, record keeping, and doing simple experiments. Farmers became aware of the relationship that exists between the organism and environment. For example, in the past, farmers could not differentiate the symptoms of bean stem maggot from fungal bean disease. After attending the FFS activities, farmers at Isuto identified the bean stem maggot and understood how and when the insect caused damage to the bean plant. This helped farmers to make decisions on how and when to control the insect. Unfortunately, as a result, farmers' group members at Isuto sprayed insecticide on the control plot, and no results were obtained from the experiment. On the other hand, farmers at Mbawi identified different fungal bean diseases, such as *Ascochyta*, *Anthracnose*, and rust, which they could not identify before. They also made plant specimens for reference.

Farmers observed the genetic differences among bean varieties tested for disease resistance and flower intensity. At Mbawi, they noted that Kabanima resisted fungal diseases better and had more flowers than any other bean variety. At Isuto, farmers observed that improved bean varieties, Uyole 94 and Uyole 96, resisted fungal diseases better than the local bean cultivar, Kablanketi.

In all villages, farmers noted that plant vigour was better for the bean plants with fertiliser than those without. At Mbawi, farmers observed that the first planting (15 March 2000) had higher disease pressure than any other planting and were less affected by drought, compared to the third planting (15 April). Farmers at Isuto observed that the second planting (30 March 2000) was more affected by drought than the first planting.

Farmers observed that semi-climbing bean cultivars with growing tips took longer to reach physiological maturity than those without growing tips.

Farmers' field days and harvesting of demonstration and experimental plots

More than 50 farmers attended the field days in each village. Discussions held after field tours during the farmers' field days revealed that participating farmers were impressed—not only with the FFS activities, but also with the confidence that farmers had when answering questions and explaining activities to other village members. Hence, farmers' field days motivated other village members to join the FFS groups. Similar observations were noted at the Tembela Division field site where four more FFS groups were initiated after conducting farmers' field days (SHERFS, 1999). Kingsley and Musante (1996) argue that the learning process is clearer and appears more practical to others when farmer group members, rather than non-farmers (such as extension officers or researchers), lead in explaining FFS activities to other village members.

Beans were harvested after farmers' field days in both villages. Results for each activity are discussed below:

- **Effect of planting time for early-maturing bean varieties** (figures 1a and 1b). Generally, the grain yield performance of all bean varieties planted at Mbawi was better in the second planting (30 March 2000) than in any other planting, with an average mean grain yield of 1335 kg/ha. This planting was farmers' practice. At Isuto, all bean varieties performed better in the first planting (1 March 2000) than in the second planting, which was farmers' practice.

Bean varieties, Kabanima and Uyole 96, out yielded other bean cultivars in all plantings and out yielded the local bean cultivar by more than 50% in some of the plantings.

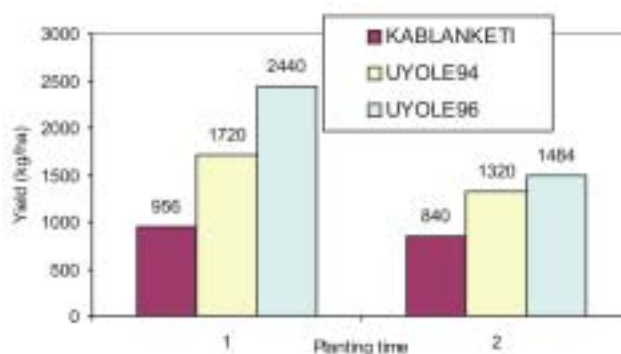


Figure 1a. Yield of bean cultivars planted at different dates at Isuto

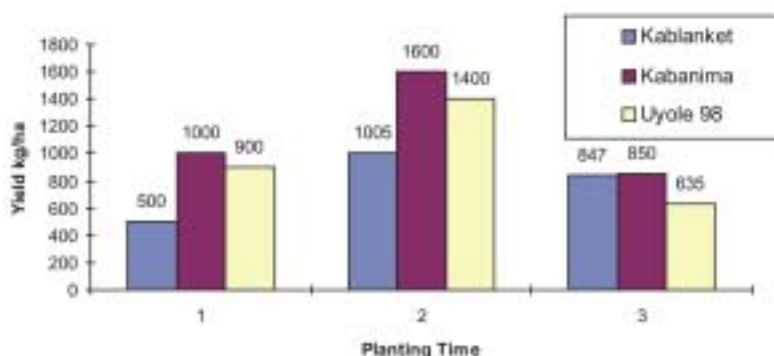


Figure 1b. Yield of bean cultivars planted at different dates at Mbawi

- **On-farm seed multiplication of early-maturing bean varieties** (figures 2a and 2b). Grain yield for the bean cultivars planted at Ilembo (another village in the Isangati Division) was better than that of

bean cultivars planted at Mbawi (figure 2a). Kabanima out yielded the local bean cultivar, Masusu, by more than 50% at Ileembo and less than 50% at Mbawi. At Isuto, Uyole 96 out yielded the other bean cultivars (by up to 50%, compared to local bean variety, Kablanketi).

- **Verification of botanical insecticides in aphid and pod borer control in bean fields.** No significant difference in yield was observed among treatments at Isuto and Mbawi villages. This could be due to low level of insect pest infestation on the bean plants which was observed by farmers during monitoring tour. Hence this experiment was requested to be repeated next season.

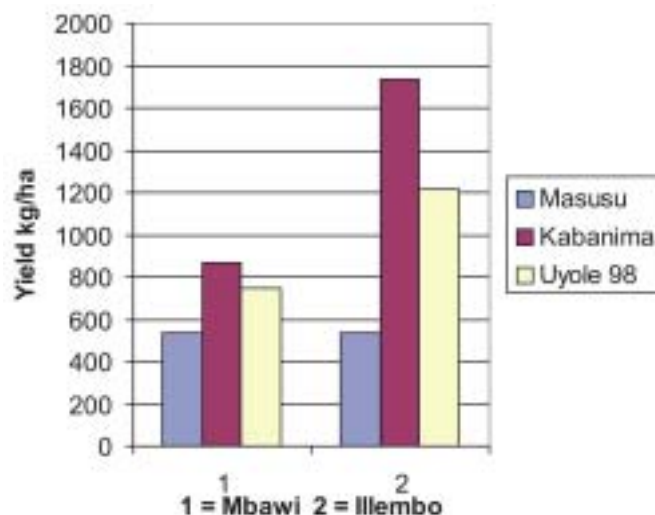


Figure 2a. Yield of bean cultivars planted at Mbawi and Ileembo

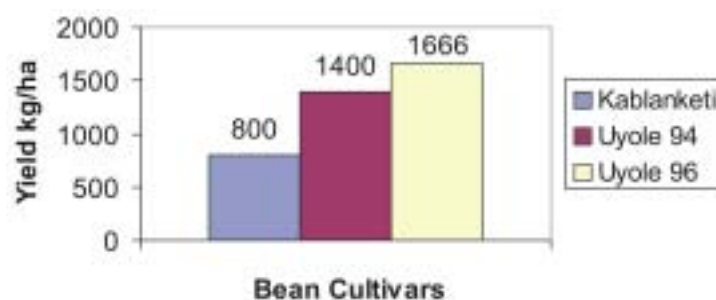


Figure 2b. Yield of bean cultivars planted at Isuto

- **Cultural Control of bean stem maggot in bean fields.** After farmers understood how important the bean stem maggot was economically, they decided to spray the whole experiment with insecticide in order to protect the beans. Hence, no significant yield difference was observed among treatments.
- **Removing the growing tip of semi-climbing bean varieties.** Farmers did not observe any significant difference in yields between bean plants with growing tips and those without. Instead, they observed differences in seed size. Plants without growing tips reached physiological maturity earlier and had large seed size than those with growing tips.
- **Use of fertilisers.** The effect of fertilisers in bean production was appreciated by farmers, and they planned to use it in future. They said that yields of bean cultivars planted with fertilisers were higher than those without fertilisers (table 1).

ASSESSMENT OF FIELD METHOD

Reason for adoption

The FFS method has high chance of being adopted as a potential methodology to develop and transfer appropriate technologies to small holder farmers in Tanzania. This is due to the fact that the method gives good impact on farmer's adoption of technologies being tested. The methodology involves farmers fully in problem identification and in development and testing of a technology designed to solve the problem.

Table 1. Mean Grain Yield (kg/ha) of Bean Cultivars Planted with and without Fertilisers at Different Dates, Mbawi Village

Planting dates	Bean varieties	With fertiliser	Without fertiliser
15 March 2000	Uyole 98	1240	560
	Kabanima	1330	670
	Kablanketi	520	480
Means		1030	543
30 March 2000	Uyole 98	2240	660
	Kabanima	24700	830
	Kablanketi	1340	670
Means		2073	687
15 April 2000	Uyole 98	860	410
	Kabanima	1090	510
	Kablanketi	1000	694
Means		983	533

Farmers critically analyse the environment and study its relationship with the organism and later make decision of whether to adopt the technology or not.

For example in the evaluation of planting time for early maturing bean varieties, farmers have began to take divisions on when to plant these bean varieties. Basing on the observations they make during monitoring and evaluations. Farmers, also, decided to multiply seed of bean varieties, which they observed to be suitable under their environment.

Differences between methods

In the FFS method, as stated earlier, farmers' problems and needs are identified and prioritised during a PRA study, making the method participatory and bottom-up. It differs from T&V because there the problems and needs of farmers are determined by researchers, making the approach top-down.

Through training and planning meetings, the FFS method considers farmers as experts in bean production and that they have something to contribute to treatment selection (in contrast to T&V, where researchers select the treatments). Farmers are given the chance to become part of the research system by incorporating their experiences in experimental activities and sharing them with others. For example, a farmer at Mbawi claimed that removal of the growing tip from semi-climbing bean plants increased the yield of beans in his field. Other farmers' group members agreed to conduct investigations on the effects of removing the growing tip from semi-climbing bean plants in their experimental plot. Farmers at Isuto included cultural control of bean stem maggots in an experimental plot because they felt that the insect was important in the area.

In the FFS approach, discussions held during monitoring and evaluation also increased interactions among stake holders, thus strengthening the research-extension-farmer linkage. At Mbawi, the stakeholders met more than six times after establishing the experimental and demonstration plots. In the T&V method, contact farmers rarely meet with other stakeholders, thereby weakening the research-extension-farmer linkage.

The FFS approach empowered farmers in decision making. For instance, farmers at Mbawi selected Kabanima and those at Isuto selected Uyole 96 for further seed multiplication and distribution in the villages, based on field observations they made during agro-ecosystem analysis. They also noted that these varieties out yielded other bean cultivars at each respective village (figures 1a and 1b). Farmers observed that Kabanima and Uyole 96 produced more flowers and showed good pod load and resistance to diseases compared to other bean varieties tested.

Similar results were observed from IPM/FFS for potatoes conducted for one season at the Tembela Division field site by the Southern Highlands Extension and Rural Financial Services (SHERFS) project (1999). Participating farmers were able to assess crop health, pest enemies, and friendly pests and their relationship to crop losses before deciding when to apply pesticides. This kind of knowledge helped the farmers in Tembela Division reduce the use of pesticides by 20% on IPM plots. In T&V, contact farmers lack such experience because every field operation is done according to the calendar of work, which is proposed by researchers. For instance, it has been recommended that bean stem maggot should be controlled within five

days after seed emergence. However, in the Southern Highlands, it has been noted that some farmers have controlled bean stem maggot in the field after the recommended time. As a result, several bean plants were destroyed by the insect. This could be because such farmers did not understand the logic behind controlling the insect at the recommended time.

T&V also has less impact on the adoption of new crop technologies amongst farmers. T&V farmers' field days are conducted by researchers or field officers, who are not considered farmers.

Cost effectiveness

The FFS approach is cost effective. The cost analysis in table 2 shows that the bean planting activity cost 401,000 shillings to serve 55 farmers using the FFS approach (7,291 shillings per farmer), while it cost 2,722,000 shillings to serve the same number of farmers using T&V (49,680 shillings per farmer).

Table 2. Cost Analysis of FFS Approach Versus T&V Method for Planting Beans

FFS Approach		T&V Method	
Number of staff	3 Research Officers (ROs) 2 ADP Staff 1 Driver	Number of staff	3 Research Officers (ROs) 2 ADP Staff 1 Driver
Number of farmers	55	Number of farmers	55
Number of days	3 days	Number of days	11 days Assumption that for one extension officer to work efficiently, he/she should serve 5 farmers per day
Land size	0.5 acres/site x 1 acre for two sites	Land size	11 hectares In T&V, each farmer plants the experimental and demonstration on his/her farm of 0.5 acre
Number of sites	2	Number of sites	55
Costs		Costs	
<i>Nights out</i>		<i>Nights out</i>	
3 R.O. @ 20,000/=	180,000/=	3 R.O. @ 20,000/=	660,000/=
x 3 days		x 11 days	
2 ADP @ 6,000/=	36,000/=	2 ADP @ 6,000/=	142,000/=
x 3 days		x 11 days	
1 driver @ 10,000/=	30,000/=	1 driver @ 10,000/=	110,000/=
x 3 days		x 11 days	
Fuel	45,000/=	Fuel	100,000/=
Sub-total	291,000/=	Sub-total	1,010,000/=
<i>Inputs</i>		<i>Inputs</i>	
Insecticide: 2 litres Selecron @ 9,000/=	18,000/=	Insecticide: 10 litres Selecron @ 9,000/=	180,000/=
<i>Fertilisers</i>		<i>Fertilisers</i>	
2 bags TSP @ 11,000/=	22,000/=	22 bags TSP @ 11,000/=	242,000/=
2 bags CAN @ 9,000/=	18,000/=	22 bags CAN @ 9,000/=	99,000/=
100kg bean seed @ 520/=	52,000/=	770kg bean seed @ 520/=	400,400/=
Sub-total	120,000/=	Sub-total	1,712,400/=
GRAND TOTAL	401,000/=	GRAND TOTAL	2,722,400/=
Cost per farmer	7,291/=	Cost per farmer	49,680/=

Problems encountered in implementing the intervention

- Female participation in farmer field schools was low, compared to men. This was noted in both villages. The women claimed that they had a lot of work to do on their farms. To improve female participation, women's farmers field schools should be initiated.
- Participation of policymakers in FFS activities is low, from the village to the regional level. To improve policymakers' involvement in FFS activities, seminars and workshops should be targeted to them.
- Although the objectives of FFS were clearly explained to farmers' groups, some of the group members dropped out because they had expected to be given loans. Farmers' groups started with 25 members at Mbawi and 30 at Isuto. Now there are only 20 members in each village.
- It was difficult for the facilitator to conduct FFS without formal training on the FFS approach. It would be better to train the facilitator before she/he undertakes the responsibility of conducting FFS.

Lessons learned

1. Facilitators should have local knowledge before conducting FFS in a community. For example, a lot of indigenous knowledge and experience was gathered in a short time during the training workshop. It is important, therefore, for facilitators to orient themselves in a community prior to initiating FFS.
2. The FFS approach can empower farmers in decision making because it provides greater experience on which they can base their decisions. During monitoring and evaluation, farmers are involved in all stages of bean production. These experiences could be further improved by encouraging farmers' groups and facilitators to visit other field school sites to see how local conditions differ, how farmers address their problems, and what approaches are used.
3. The FFS approach establishes effective linkages and partnerships among stakeholders, especially during monitoring and evaluation, when there is a lot of interaction among stakeholders.
4. The approach develops an organised group of farmers who are experts in bean production, which can later serve other farmers in the village. To improve the situation, such groups should be recognised by the government and supported.
5. FFS can quickly spread information on new improved technologies in a community and motivates other groups to join FFS groups. For instance, a women's church group from Ilembu asked to join the FFS group after hearing from their neighbours about the introductory FFS meeting and the formation of farmers' groups. To improve the situation, leaflets on FFS should be distributed in the community during that meeting.
6. The FFS approach can be cost effective.

RELEVANCE TO THE COUNTRY AND TO THE REGION

The FFS approach, as a method for appropriate technology development and transfer to smallholder farmers in Tanzania and in the other parts of the region, is very relevant and has a high chance of being adapted because of the following reasons:

- The ratio of farmers to extension staff in the field is invariably high. It has been documented that only seven village extension officers serve 27 villages in Isangati Division. Spore (1997) reported similar trends throughout the African continent. The use of the FFS approach in such situations could help to speed up the diffusion and adoption of new technologies among smallholder farmers. Dilts and Hate (1996) argue that the goal of FFS is not just to bring skills to a set of individual farmers but to develop an organised group of farmer 'experts' who can serve other farmers in the village.
- Lack of funds is a common problem all over the region. There are insufficient funds for transport and supporting materials to allow extension agents to serve all farmers' needs. Hence, a choice must be made of where extension inputs are most likely to have the greatest impact. The FFS approach appears to be a possible solution.
- In Tanzania and in the other parts of the region, farmers' priority problems and needs have been ignored in technology development for too long. With the FFS approach, men and women with varying responsibilities on their farms and in their communities can participate in formulating plans and can receive recognition for their indigenous knowledge.

- About 85% of the population in Tanzania is mostly smallholder farmers who live in rural areas where access to information about new technologies is limited. Many smallholder farmers do not even have a radio or the time to listen to radio news. The FFS approach provides access to information while generating enthusiasm among participating farmers during the implementation of FFS activities.

Prospects for FFS institutionalisation in the country are high but well-defined problems and trained and dedicated facilitators are required. In Tanzania, very few facilitators are trained in FFS concepts and most farmers' problems and needs are not well prioritised. Political commitment in terms of formulating policies that favour FFS and providing resource support to FFS is lacking.

Successful FFS require well-trained, dedicated facilitators, adequate resources, and good logistical support. All stakeholders in FFS should have a clear understanding of the concept, and authorities at all levels should support the FFS approach.

CONCLUSION

FFS is a useful approach to technology and to targeting dissemination, and it can complement other approaches, such as farmer-to-farmer, farmers' groups, PEA, FSA, and PRA.

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DEVELOPMENT AND PROMOTION OF IPM TECHNOLOGIES FOR COMMON BEANS FOR SMALLHOLDER FARMERS IN NORTHERN SUDAN

F. L. Oji and S. A. Mohamed

ABSTRACT

*The common bean plays a major role in Sudan's economy. It is second in importance to faba bean in terms of production and consumption and provides a cheap source of protein for smallholder farmers and a source of cash. Insect pests are the major biotic constraints to the production of the crop, although no post-harvest pests (bruchids) have been recorded in any of the locations surveyed: beans can be stored without protection up to 15 years without any bruchid damage. Results from a survey carried out to generate information on farmers' perceptions and management of bean pests revealed that smallholder farmers do not know the biology of insects and tend to think that all insects observed in their fields are harmful. Insect pests in farmers' fields remain largely uncontrolled due to farmers' financial constraints and ignorance of the level of infestation. In cases where pesticides are used, the danger is not overuse of the pesticide but misuse. The challenge for research is to develop simple, affordable, environmentally friendly, and sustainable pest-control methods and methods of promoting developed technologies. Results from a three-season on-station experiment and one on-farm demonstration revealed that the use of cultural practices, such as intercropping with *Coriandrum sativum* as a whitefly repellent, were consistently and significantly effective in reducing the whitefly population in bean fields. The *Coriandrum* was also observed to be a good reservoir of natural enemies and honey bees. Neem seed extract and a powder from *Acacia stenophylla* pod extract had slow but effective results on whitefly when compared to the untreated check. However, intercropping with *Coriandrum* received more acceptance by farmers because of its repellent effect on pests and the fact that it is an additional product that can be sold to earn extra cash. Neem seed extract was the best botanical insecticide that was accepted: neem is found in almost all households as a shade tree and its extract can easily be processed and used without fear of being poisoned.*

RÉSUMÉ

*Le haricot commun joue un rôle essentiel dans l'économie du Soudan. Il occupe la seconde place après la fève en termes de production et de consommation et constitue une source bon marché de protéines ainsi qu'une source de revenus pour les petits exploitants agricoles. Les insectes ravageurs représentent la principale contrainte biotique de cette culture, bien qu'aucun ravageur après récolte (bruches) n'ait été enregistré dans les emplacements examinés. Les haricots peuvent être entreposés sans protection pendant une quinzaine d'années sans subir de dommages liés aux bruches. Une étude menée auprès des agriculteurs sur leur perception et leur gestion des ravageurs du haricot a révélé que les petits exploitants agricoles ne connaissent pas la biologie des insectes et ont tendance à penser que tous les insectes observés sur leurs champs sont nuisibles. Les insectes ravageurs demeurent dans l'ensemble non maîtrisés du fait des contraintes financières et de l'ignorance du niveau d'infestation. Lorsque des pesticides sont utilisés, le danger est leur emploi inapproprié plutôt qu'excessif. La recherche a pour défi d'élaborer des méthodes de lutte contre les ravageurs simples, d'un prix abordable, respectueuses de l'environnement et durables ainsi que de bonnes stratégies de promotion. Les résultats d'une expérience à la station de recherche sur trois saisons et d'une démonstration en situation réelle ont révélé que l'utilisation de pratiques de cultures, telles que la culture associée de *Coriandrum sativum* (coriandre) en tant qu'insectifuge de la mouche blanche (Aleurode) permettait de réduire de manière efficace et significative la population de mouches blanches dans les champs de haricots. *Coriandrum* s'était révélé un bon réservoir d'ennemis naturels et d'abeilles. Les extraits de graines de margousier et une poudre provenant de gousses d'*Acacia stenophylla* avaient montré des résultats lents mais efficaces contre les mouches blanches en comparaison avec la parcelle témoin non traitée. Toutefois les agriculteurs préféraient la culture associée de *Coriandrum* du fait de son effet répulsif contre les ravageurs et des revenus supplémentaires que représente la vente du coriandre. Les extraits de graines de margousier étaient l'insecticide botanique le mieux accepté. Cet arbre apprécié pour son ombre se trouve souvent aux abords des maisons et l'extrait de ses graines peut être facilement traité et utilisé sans risque d'empoisonnement.*

INTRODUCTION

The common bean plays a major role in Sudan's economy, second in importance to faba bean in terms of consumption and production. It is a cheap source of protein for smallholder farmers (Mohamed and Salih, 1990) and a good source of cash; farmers can fetch a high price in the nearby Arab world market. The production of the crop is limited by a number of constraints, such as poor cultural practices, pests and diseases, soil salinity, and lack of certified seeds (Salih et al., 1990). Insect pests are one of the most important constraints to bean production in Africa, causing yield losses of up to 100% (Karel and Autrique, 1989). In the northern Sudan, whitefly, *Bemisia tabaci* (Gen.), is the number one enemy of the crop. In years of heavy infestation, the pest completely devastates the crop. Aside from causing direct damage, it acts as a vector of viral diseases (Allen, 1987).

Informal survey results and field observations indicate that other pests, such as African bollworms, are gaining economic importance. Because most smallholder farmers have very little land, which is continuously divided as the family expands, crop rotation is not possible and often results in a build-up of pests and diseases.

In such situations, the challenge to research is to collect information on the farmers' perceptions of pests and their management, in order to develop simple, affordable, environmentally friendly, and sustainable methods of pest control. That was the objective of this study.

MATERIALS AND METHODS

Survey on farmers' perception and management of bean pests

Informal surveys and field observations have indicated that damage caused by insect pests, in general, has reached an alarming level. This necessitates conducting strategic studies to collect concrete information on the types of pests attacking beans and the extent of damage caused. To this effect, a questionnaire survey was carried out on farmers' perceptions of and attitudes toward insect pest problems in the major bean-growing areas. In total, 84 farmers were interviewed: 20 in Shendi, 17 in Gadawab, 18 in Nahri Atbara, 11 in Selwa, and 18 in Berber. They were asked about insect pests attacking the common bean, the extent of damage caused by each pest, control methods practiced, and other related factors. Insect counts were taken in each farmer's field on 10 randomly selected plants. Each crop was visually inspected for the adults, larvae, and eggs of the pests, along with damage symptoms and the presence of natural enemies. The plants were also shaken to take note of any flying or falling insects. A board bearing pictures of insects known to be bean pests was used to help farmers identify insects that inflict damage on the crop.

Evaluation of some botanical and chemical insecticides in the bean field

Efforts were made for three successive seasons in Hudeiba Research Station and for one season in on-farm demonstrations to develop simple, affordable, environmentally friendly, and sustainable methods of pest control for the smallholder farmers. Trials consisted of the following treatments, including Somicidin (0.3ml/litre of water) as a standard check: intercropping with coriander, neem seed extract (0.3ml/litre of water), *A. stenophylla* pod powder extract (1kg/50 litres of water), plain water as a control.

In the on-farm demonstration, neem seed extract at 1kg/80 litres and ash (1kg/42m²), based on farmers' practice, were added to the original five treatments.

In a completely randomised block design with four replications, seeds of variety RO/2/1 were sown in plots measuring 7m x 6m. Coriander was sown between the bean plants. Parameters were adult whitefly counts and yield (kg/ha). The whitefly population density was counted on two top, one middle, and two lower leaves on five randomly selected plants per plot. All cultural operations were as per ARC standards. Extracts of neem seed and *A. stenophylla* pod powder were prepared as follows: neem seed kernels or *A. stenophylla* pods were pounded in a wooden mortar to a paste or powder. The paste or powder was then mixed with the right amount of water in plastic containers. Using a stick, the contents were thoroughly stirred and left overnight in a tightly closed plastic container. In the next morning it was stirred again then sieved to remove residues that might block sprayer nozzles.

The pesticides were sprayed as per the application rates indicated above, using three-gallon pneumatic knapsack sprayer. Ash was dusted on the beans by hand. Analysis of variance and Duncan's Multiple Range Test (DMRT) were performed (table 1). Two dosage levels were used for neem seed extract in the 2000/2001 season (table 1).

Table 1. Effect of Coriander and Selected Insecticides on Whitefly Populations and Yields of Common Beans

Treatment	Pre-spray count	Post-spray count			Yield kg/ha
		3 Days	7 Days	14 Days	
1997/1998 season					
Intercropping with coriander	5.5	5.1	1.3	1.9	2013
Sumicidin	5.5	5.9	1.2	2.2	2076
Neem seed extract	4.9	5.2	1.1	5.9	2405
<i>A. stenophylla</i> pod powder	5.3	5.4	1.4	4.2	2130
Control	4.9	5.9	1.4	6.2	2162
C.V.(%)	0.2	0.3	—	0.9	24.7
S.E.±	7.5	10.0	30.5	43.5	23.4
Level/sign	*	ns	ns	*	ns
1998/1999 season					
Intercropping with coriander	10.4	8.7	7.2	4.0	1256
Sumicidin	18.9	10.2	8.6	5.0	1070
Neem seed extract	16.4	11.2	9.1	4.7	1025
<i>A. stenophylla</i> pod powder	16.4	12.3	11.2	4.0	905
Control	17.1	22.3	14.7	17.2	700
C.V.(%)	16.2	24.1	18.3	41.6	17.4
S.E.±	0.3	0.4	0.2	0.4	236.5
Level/sign	**	***	***	***	*
1999/2000 season					
Intercropping with coriander	4.3	1.3	3.6	1.3	1515
Sumicidin	9.8	0.7	1.2	1.0	1600
Neem seed extract	9.6	5.4	1.3	1.5	1465
<i>A. stenophylla</i> pod powder	9.9	4.8	2.6	1.2	1480
Control	11.6	6.7	5.4	1.9	960
C.V.(%)	12.5	44.9	44.3	25.9	22.3
S.E.±	0.6	0.9	0.8	0.2	391.5
Level/sign	***	**	*	*	*
2000/2001 season					
Intercropping with coriander	5.0	3.7	3.0	3.5	2400
Sumicidin	18.0	1.3	1.5	1.0	2660
Neem seed extract (1kg/80 litres)	16.3	5.5	5.0	4.3	1860
Neem seed extract (1kg/40 litres)	13.3	5.0	4.0	3.7	1980
<i>A. stenophylla</i> pod powder	16.5	5.7	5.0	3.3	1900
Ash	14.0	12.5	14.3	14.8	1200
Control	18.0	17.0	17.5	16.3	1000
C.V.(%)	14.5	20.7	15.0	17.4	31.3
S.E.±	1.0	0.7	0.5	0.6	72.7
Level/sign	***	***	***	***	**

Note: Figures for mean # of whiteflies/100 leaves transformed to $\sqrt{x+1}$.

* $p < .05$.

** $p < .01$.

*** $p < .001$.

RESULTS AND DISCUSSION

Survey of farmers' perceptions and management of bean pests

Based on the results of the survey, damage from insect pests occurs every year on common beans (table 2). The major insect pests identified, in order of their economic importance, were whiteflies, *Bemisia tabaci* (Gen.); African bollworms, *Helicoverpa armigera* (Hub.); cutworms, *Agrotis ipsilon* (Hufnagel); leaf miners, *Lirimyza congesta* (Becker); aphids, *Aphis craccivora* (Knock); thrips, *Caliothrips impurus* (Pries); rats, *Mastomys natalensis macrolepis* (Sund.), especially near human settlements; desert locust, *Shistocerca gregaria* (Forsk.); spidermites, *Tetranychus cinnabarinus* (Boisd.); and jassids, *Empoasca lybica* (De Berg.). Natural enemies observed were lacewings, *Chrysoperla carnea*; unidentified syrphidfly and *Coccinella* spp.

Table 2. Consistency of Pest Damage from Year to Year

Pest	Number of farmers classifying pest as very severe	Percent of farmers classifying pest as very severe		
		Every year	Some years	Rarely
Whiteflies	73	93	7	0
African bollworms	70	41	35	24
Cutworms	32	80	20	0
Leaf miners	15	79	16	5
Aphids	10	14	86	0
Thrips	9	63	30	7
Rats	8	0	57	43
Desert locust	6	0	0	100

Fifty-seven percent of the farmers in Selwa and 50% in Nahri Atbara classified African bollworms as a severe pest. This was confirmed by direct field counts. According to farmers' observations, the pest is more severe when the wind blows from the northeast (Hawashergi). At Gadawab, 55% of the farmers indicated that whiteflies were responsible for their low crop yields because there was no time when the pest was completely absent from the bean fields. Cutworms were classified by 35% of the farmers in Berber as a very severe pest, mainly in weedy fields, and they pointed out that two tillage operations before sowing can substantially reduce cutworm damage. This view was shared by farmers in Gadawab and Selwa. Most farmers felt that aphids were a pest of faba beans; however, 35% of farmers in Shendi reported that aphids caused damage to their common beans.

None of the farmers interviewed know the biology of insects (in fact, some farmers claim that pest problems are due to pest eggs being mixed with insecticides by chemical companies), and they regarded some predators as pests. Bentley and Andrews (1991) state that farmers are observant and rely on their own creativity to help them survive on scarce resources. However, they lack a well-developed concept of natural enemies and tend to think that all insects are harmful.

Although farmers are aware of the damage caused by insect pests, these pests remain largely uncontrolled due to farmers' ignorance of the pest status of their fields and what chemical to use. Of 84 farmers interviewed, only 10% (8) used chemical pesticides. They wear ordinary clothes when spraying chemicals, and the use of a tomato paste tin full of chemical to one gallon of water is a common practice. This dose is the same for all chemicals encountered. Sengooba (1991) has mentioned that the problem with pesticide use in resource-poor farmers' fields is not overuse but misuse. Insecticides mentioned to have been used were Sevin, malathion, fenitrothion, and dimethioate, which means that these farmers might have sprayed other chemicals because dimethioate and fenitrothion are not found in this region.

Ninety percent of the farmers did not spray their crops, either because the control method is expensive or unknown, or because no time is available. However, most farmers were aware of manipulating the sowing date as a way to control pests. Although the common bean is mainly grown as a sole crop, some farmers practice mixed cropping with lubia (*Dolachus lablab*) as a whitefly attractant (bait), which can be used as animal fodder later on.

No post-harvest bean pests (bruchids, *Bruchidus incarnatus* Boheman) have been recorded in any of the locations surveyed. Farmers hold that the common bean—unlike faba beans and chickpeas—is not a risky crop to store. It can be stored up to 15 years without any bruchid damage. Although the mechanism of common bean resistance to bruchid damage in stores is possibly an antibiosis reaction, 78% of the farmers attributed it to its hard, cement-like and slippery testa. Most respondents (98%) indicated that they leave their beans in the field after harvesting for two weeks or more while doing other pressing field work and thresh the beans during their leisure time.

Evaluation of some botanical and chemical insecticides in bean fields

Results from both on-station trials and on-farm demonstrations revealed whiteflies on bean plants immediately after the first true leaves began to unfold. Kisha (1981) indicated that whitefly eggs were observed on tomato plants immediately upon germination. Statistical analysis of the data showed that intercropping the common bean with coriander as a whitefly repellent was consistently and significantly effective in repelling whiteflies and improving bean yields (table 1). Similar results were observed with tomatoes (Abdelrahman, Nafisa et al., 1995; Abdelrahman, Mamoun et al., 1992; Ahmed 1994; Ahmed et al., 1994). To be effective, coriander has to be fresh and green. Its maximum repellence is attained at flowering time. Coriander was also observed to be a good reservoir of natural enemies and honey bees. Dent, (1991) mentions that a variety of crops, if present together, create perfect conditions for the presence of natural enemies. Although coriander compares favourably with sumicidin, as a chemical insecticide the sumicidin is, however, superior in most cases. However, no significant difference could be detected in bean yields between sumicidin and coriander as an intercrop. Neem seed and *A. stenophylla* pod powder extracts were slow in affecting the whitefly; however, both botanicals resulted in higher yields than the untreated control. Saddig (1991) indicated that neem seed extract controls pests through three modes of action: repellent, antifeedant, and growth regulation, in addition to a comparatively weaker insecticidal effect.

Although sumicidin was superior in the on-farm demonstration (table 1), coriander maintained its good repellent effect on whiteflies and significantly ($p < .001$) improved the bean yield (2400 kg/ha) compared to the untreated control (1000 kg/ha). Intercropping common beans with coriander was more highly accepted by the farmers because of its repellent effect on pests and the fact that it is an additional product that can be sold to earn some cash. Neem seed extract was the most highly accepted botanical insecticide because the tree is used as a shade tree around almost all houses and its extract can be easily processed and used without fear of getting poisoned. Dusting the common bean with ash to control whiteflies did not significantly differ from the untreated control in regard to the bean yield.

Socio-economic feasibility

The positive attitude shown by farmers to the on-farm demonstration results does not mean that the technology will be adopted in its first year of application. More work is still going on to draw concrete conclusions. Generally, farmers are conservative and do not change their traditional practices unless they are convinced of obvious benefits. The impact of cultural practices and botanicals on pests is not as immediate as most synthetic chemicals, which are preferred by some farmers. For such farmers, cultural practices and botanicals will not be satisfactory. However, these methods are alternatives for those farmers who can not afford or do not want to use chemical insecticides.

In regard to promoting IPM technologies, the participatory approach has both advantages and disadvantages:

Advantages

- strengthens linkages between farmers, extensionists, and researchers
- the biology of pests and causes of pest resurgence are better explained by scientists
- scientists can benefit from farmers' experience
- scientists become familiar with farmers' pest problems and how they respond to them
- farmers become willing to learn and change—can lead to development of self-sustaining rural network

Disadvantages

- farmers expect material help
- farmers may drag politics into on-farm discussions, which may be disastrous to the whole program
- frequent visits to farmers' fields and late arrivals home may cause family problems

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BEAN SELECTION IN PARTNERSHIP WITH FARMERS IN ZAMBIA

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ABSTRACT

In Zambia, beans rank second after groundnuts among the food legumes, but the yields of 300 kg/ha to 500 kg/ha in farmers' fields are far below the potential of 1500 kg/ha to 2000 kg/ha. In 1985 the Food Legumes Research Team released a variety, Carioca, because of its high yields and resistance to major bean diseases. Little attention was given to the seed type, size, and colour, and the variety was not well accepted due to its 'flat' taste, colour, and small seed size. The team in Zambia, in partnership with farmers, has worked on improving yield by genetic improvement in combination with cultural practices that include spacing, seed dressing, time of planting, etc. Through close collaboration with the Southern African Bean Research Network (SABRN) and International Center for Tropical Agriculture (CIAT) headquarters, the team has managed to identify three lines that proved better in terms of yield, resistance to disease, and acceptability with farmers. In the last half of the decade, the team managed to work with farmers in identifying preferred lines and, as a result, three varieties have been released: Chambeshi (A197), Lyambai (CAL 143), and Lukupa (PEF 14).

RÉSUMÉ

En Zambie, le haricot vient en seconde position après les arachides sur le plan de la culture des légumineuses. Toutefois, les rendements en situation réelle, qui sont de 300 kg/ha à 500 kg/ha, se situent bien en deçà des possibilités estimées à 1500 kg/ha voire 2000 kg/ha. En 1985, le Programme légumineuses a introduit Carioca, une variété à haut rendement et résistante aux principales maladies du haricot. Peu d'attention avait été accordée au type de semence, à sa taille et à sa couleur, et la variété n'avait pas été bien acceptée du fait de son goût fade, de sa couleur et de la petite taille des graines. L'équipe de Zambie, en collaboration avec les agriculteurs, a travaillé sur l'augmentation des rendements en associant améliorations génétiques et pratiques culturales telles que l'espacement entre les semis, la désinfection des semences, l'époque de plantation, etc. Grâce à une collaboration étroite avec les sièges du Southern African Bean Research Network (SABRN) et du Centre international d'agriculture tropicale (CIAT), l'équipe est parvenue à identifier trois lignées qui se sont révélées les meilleures en termes de rendement, résistance aux maladies et acceptation de la part des agriculteurs. Au cours des cinq années suivantes, l'équipe a réussi en collaboration avec des agriculteurs à identifier des lignées ayant la préférence. C'est ainsi que trois variétés suivantes ont été introduites : Chambeshi (A197), Lyambai (CAL 143) et Lukupa (PEF 14).

INTRODUCTION

The bean programme in Zambia has focused its research on improving lines that are not only high yielding but also preferred by farmers. When Carioca was released in 1995, it received a mixed reception from farmers because of its small seed size and flat taste, even though it was quite high yielding compared to the local varieties. While the importance of key breeding activities on research stations cannot be questioned, the objective of participatory research is not only to identify potential new varieties within the technical and scientific framework, but what is also crucial is to transfer evaluation processes to the end users (that is, the farmers) from a range of diverse social and economic backgrounds, to empower them to participate at the earliest stage in selecting appropriate varieties for their use (Scott 1995; and Scott and Maiden, 1998).

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In bean research it is important to work with farmers in selecting materials, from the point of view of planting, harvesting, cooking, and storage. Farmers normally look at different characteristics in choosing a variety, some of which are seed colour, seed size, growth habit, and resistance to insect pests and diseases. Further selection can be based on cooking time and taste. With the close collaboration with farmers, the Food Legumes Team in Zambia managed to release three bean varieties: Chambeshi (A 197), released in 1998, and Lyambai (CAL 143) and Lukupa (PEF 14), both released in 1999.

This paper discusses the collaboration between researchers and farmers in coming up with varieties selected by both parties. This work involved farmers in making selections at different stages of the bean crop.

MATERIALS AND METHODS

The work, which started with researchers selecting the materials, was taken on-farm in the bean-growing areas of the country: Kapatu, Nsokolo, and Mungwi in the Northern Province; Solwezi and Mwinilunga in the North Western Province; and Lundazi and Chipata in the Eastern Province.

A number of on-farm trials (OFTs) and demonstrations were conducted, with a total of four new varieties and one local check. Plot sizes of 5 x 5 were used, with a spacing of 60 cm x 10 cm planted on ridges. Basal dressing fertiliser (Compound D) was applied at the rate of 150 kg/ha at planting. The seed was either dressed with Endosulphan (5 g of Endosulphan 50% WP mixed with 1 kg of seed) or Furadan granules sprinkled in planting furrows at planting at the rate of 12 kg/ha.

The plant stand was recorded at emergence and harvest. The incidence of disease and insect pests was also recorded.

Farmers were invited to the sites to make selections at different stages of crop growth. The crop was also assessed in terms of disease and insect pests. Further selections, based on seed type, colour, and size, were made after harvest.

RESULTS AND DISCUSSION

The results showed that farmers have other characteristics than yield alone, which they consider to be very important when choosing bean varieties (table 1).

Table 1. Farmers' Scores, by Important Characteristics in Selecting Bean Varieties

Characteristic	Variety				
	PAT 10	Lukupa	Lyambai	Chambeshi	Local
Early flowering	3	1	2	2	3
Seed size	4	3	1	1	2
Seed colour	3	3	1	1	1
Growth habit	2	4	1	1	3
Early Maturing	3	1	3	3	3
Vegetative vigour	2	3	1	1	4
Reaction to pests	2	4	2	2	3
Reaction to disease	2	3	2	3	4
Marketability	5	3	1	2	1
Yield	1	1	1	1	4
Total	27	26	15	17	28
Rank	4	3	1	2	5

Note: Scores ranged from 1 to 5, where 1 = Very good, 2 = Good, 3 = Fair, 4 = Poor, and 5 = Very poor.

Lukupa yielded better overall—100% over the local variety (table 2). Emergence was not significantly different between any of the varieties. At the flowering stage, all the varieties were recommended as they had a lot of flowers. Compared to the other varieties, the farmers liked Lukupa for early flowering.

Table 2. Yield Performance of Improved Varieties Compared to Local

Variety	Yield Kg/ha						Average	% Increase over local
	Northern Province				NWP	LP		
	Kapatu	Kasama	Mwenge I	Mwenge II	Solwezi	Nchelenge		
Lukupa	1500	631	750	792	1181	542	899	100
Lyambai	1458	592	458	250	1005	375	690	53
PAT 10	1200	460	440	280	940	360	613	36
Chambeshi	1500	413	583	333	830	458	686	52
Local	625	171	292	792	610	208	450	

Note: 'NWP' is the North Western Province and 'LP' is Luapula Province.

At all the sites, farmers were very impressed with the erect growth habit of Chambeshi, Lyambai, and PAT 10 but not so impressed with Lukupa, which is an indeterminate dwarf. The farmers liked Lyambai and Chambeshi for good pod clearance, compared to the other varieties.

The reaction to diseases was assessed and Lyambai and PAT 10 were found to be better in terms of disease resistance, followed by Chambeshi, Lukupa, and the local. Chambeshi had some symptoms of angular leaf spot, but, except for bean stem maggot, it was not so easy to assess the presence of most pests.

When farmers were asked to choose the variety they liked in terms of seed size, most preferred Chambeshi for its large seeds and indicated that this would fill a bag faster than the small ones. Although PAT 10 was high yielding, it was rejected for seed size and colour, farmers said it was rather poor for marketing purposes. Lyambai was liked for its colour, which farmers said would sell fast and fetch a high price. Farmers liked Lukupa for its early-maturing characteristic, which would allow for two crops per growing season.

Farmers prefer a variety that will sell fast. They indicated that they still grow their local varieties because of their high market value, even though they were low yielding.

CONCLUSIONS

This work has shown that farmers are sophisticated in their variety evaluations, and that the criteria that are often used by scientists (such as yield and pest and disease resistance) are often not the key criteria by which farmers judge the new varieties. Therefore, it is recommended that in bean research, farmers should be involved in the selection of new varieties in order to avoid the non-adoption of varieties which are perceived to be good by researchers. From our results, it was found that PAT 10, though good yielding and resistant to pests and diseases, would not be easy to release because the end users did not like it.

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ASSESSING THE QUALITY OF PARTICIPATION IN FARMERS' RESEARCH GROUPS IN THE HIGHLANDS OF KABALE, UGANDA

Pascal C. Sanginga, Nina K. Lilja, and Jackson Tumwine

ABSTRACT

Institutionalising farmer participatory research requires developing and strengthening community-based adaptive research capacities, which can be achieved through working with groups of farmers, rather than individuals. In recent years, there has been increasing interest in farmers' research groups (FRGs) as a mechanism to catalyse farmer participation in research and to widen the impact of participatory research. However, there is a dearth of systematic empirical studies that evaluate the quality of FRG participation. This paper analyses the quality of participation in farmers' research groups in Kabale, Uganda. The paper investigates what types of participatory research were done at the different stages of the research process, how farmer participation occurred, who participates in FRGs, what the factors that determined farmers' participation in FRGs are, and what criteria should be used in monitoring and evaluating the performance of FRGs. Results showed that the types of participation were more of a functional consultative and collaborative type, but varied in the different stages of the research process as farmers increasingly took on more roles and responsibilities. The results did not support the hypothesis that participatory research may exclude women and poor farmers who may not be able to absorb the cost of participation. The probability of participating in FRGs was higher for women compared to men, and there were no significant differences in wealth circumstances between FRG members and the rest of the community. The paper highlights some performance criteria used for monitoring and evaluating the impact of FRGs, with a focus on process outcomes, particularly improvements in human and social capital, reach, and dissemination, which can be observed in the short and medium term. The success of FRGs requires significant support and personal commitment from researchers to broaden the scope of FRGs from a functional consultative approach to a more collegial, empowering one, to include broader developmental issues such as natural resources management.

RÉSUMÉ

Le développement et le renforcement des capacités de la recherche adaptative fondée sur la communauté, par le biais de la collaboration avec des groupes d'agriculteurs plutôt qu'avec des exploitants pris individuellement, ont permis de donner un cadre à la recherche participative. Ces dernières années ont été marquées par un intérêt croissant pour les Groupes de recherche d'agriculteurs (farmer research groups ou FRG) en tant que catalyseur de la participation des agriculteurs à la recherche et de l'élargissement de l'impact de la recherche participative. Il n'existe toutefois aucune étude empirique systématique qui évalue la qualité de la participation de ces groupes. Le présent document réalise cette évaluation dans le cadre des groupes de recherche d'agriculteurs de la région de Kabale, en Ouganda. Il étudie les différents types de recherche participative dans les différentes phases du processus de recherche, l'identité des participants aux FRG, les facteurs ayant déterminé la participation des agriculteurs et les critères à utiliser dans le suivi et l'évaluation des résultats des FRG. Des résultats ont montré que la participation était plutôt de nature consultative spécialisée et collaborative, mais qu'elle variait selon les phases du processus de recherche, dans la mesure où les agriculteurs prenaient de plus en plus d'initiatives et de responsabilités. Les résultats ne corroborent pas l'hypothèse selon laquelle la recherche participative pourrait exclure les femmes et les exploitants pauvres qui ne seraient pas en mesure d'assumer les coûts de la participation. La probabilité de participer aux FRG était plus élevée pour les femmes que pour les hommes et il n'existait pas de différences significatives au niveau de la richesse entre les membres du FRG et le reste de la communauté. L'étude met en évidence certains

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critères de réalisation utilisés pour contrôler et évaluer les impacts des FRG en mettant l'accent sur les résultats de fonctionnement, tout particulièrement les améliorations au niveau du capital humain et social, la portée et la diffusion pouvant être observées à court et à moyen terme. Le succès des FRG nécessite un soutien et un engagement personnels de la part des chercheurs afin d'élargir la portée des FRG pour que l'approche ne soit pas uniquement consultative mais devienne davantage collégiale et plus orientée vers l'amélioration des chances, afin d'inclure des questions plus larges liées au développement telles que la gestion des ressources naturelles.

Key words: *Quality of participation, Farmer research groups, Gender, Participatory research, Performance criteria, Uganda*

INTRODUCTION

Farmer participatory research (FPR) is increasingly receiving considerable recognition in both international and national agricultural research and development (R&D) organisations as an important strategic research issue, vital to achieving impacts that benefit poor people in marginal, diverse, and complex environments (Chambers et al., 1989; PRGA, 1997). There is now a large body of literature that demonstrates considerable advantages and potential in involving farmers in the research process (Okali et al., 1994; Pretty, 1995; Ashby et al., 1995; Martin and Sherrington, 1997; PRGA, 1997; Ashby et al., 2000; Braun et al., 2000). It is argued that FPR can significantly improve the functional efficiency of formal research (better technologies, more widely adopted, faster and wider impact), empower marginalised people and groups to strengthen their own decision making, and enhance research capacity to make effective demands on research and extension services (Martin and Sherrington, 1997; PRGA, 1997), and thus have payoffs for both farmers and scientists (Humphries et al., 2000). It is becoming increasingly imperative that priority be given to consolidating, mainstreaming, and institutionalising participatory research in national and international research organisations (Ashby et al., 1995; Ashby and Sperling, 1994).

Institutionalising FPR requires developing and strengthening community-based adaptive research capacity, which can be achieved by working with groups of farmers, rather than individuals (Ashby and Sperling, 1994). However, until recently, FPR professionals have tended to work with individual farmers (Pretty, 1995), and may not have the skills to work with groups (Ashby and Sperling, 1994). The importance of groups in FPR has been largely underestimated. Yet, it has been pointed out that 'when individual farmers are the researchers' point of contact, there is nothing to ensure that other farmers will learn from their experiences: participation is often limited to a handful of farmers who have plots on their fields' (Bebbington et al., 1994:2-3). While working with individual farmers has been a centralised process, controlled by researchers and focusing on technology, working with groups is a more decentralised process, which can be owned by farmers and can focus more on the learning and empowerment of farmers (Jassey, 2000).

In recent years, there has been increasing interest in using community-based approaches to catalyse farmer participation in research, and to widen the impact of participatory research. It is argued that the group approach is more effective because it promotes the collective learning and exchanges that occur in group settings (Heinrich, 1993; Hagmann et al., 1999) and ensures that more people participate, thus making participatory research cost-effective and relevant to the needs of different categories of farmers (Bebbington et al., 1994; Pretty, 1995; Ashby et al., 2000; Braun et al., 2000). Given the diversity and complexity of farmers' needs, the more people participate in the research process, the better the benefits should be, particularly if groups can act as intermediaries and take on some of the cost of communication with members and other farmers. Then they can generate efficiency savings in the process of participation (Carney, 1997:118).

Notable examples of approaches to group-based participatory research that are spreading widely include the local agricultural research committees (CIALs) in Latin America (Ashby et al., 1995; Braun et al., 2000; Ashby et al., 2000; Humphries et al., 2000), farmers' field schools (FFS) in Asia (Braun et al., 2000), and farmers' research groups (FRGs) in southern and eastern Africa (Farley, 1999; Jassey, 2000). An additional important advantage of farmers' research groups is to ensure that the risk is shared and not borne by individuals, and the products of the research process are public goods because they can be delivered as locally adapted technologies to a large number of people. Furthermore, FRGs may also be the most culturally acceptable way of working with farmers in most rural African societies (Jassey 2000). Over the past five years, the African Highlands Initiative (AHI) has made substantial efforts to catalyse and promote participatory research in natural resource management in five countries in eastern Africa (Ethiopia, Kenya, Madagascar, Uganda, and Tanzania). Similarly, the International Center for Tropical Agriculture (CIAT), in

collaboration with national agricultural R&D organisations, established the Participatory Research for Improved Agro-Ecosystem Management (PRIAM) project, which is supporting community-based participatory research projects in six countries in East Africa (Farley, 1999). The approaches of both PRIAM and AHI emphasise the use and formation of FRGs as a strategy central to participatory research. The approach is also rapidly gaining ground and attracting the attention of many other R&D institutions to address agricultural and natural resource management problems in the region.

While there is widespread support for FRGs in participatory research, the issue of assessing the quality of participation in FRGs is of central concern. However, there is a dearth of systematic and empirical studies on evaluating participation in farmer research groups. We still lack authoritative insights into this complex issue (Oakley, 1992; Okali et al., 1994; Ashby, 1997). Yet such analysis is critical to building more effective ways of organising and working with farmers' groups, building their capacity to innovate and experiment, and facilitating the sharing of experiences, knowledge, and skills among farmers. This paper presents the results of an empirical study to assess the quality of participation in FRGs, using data from 21 FRGs in AHI benchmark sites in Kabale, Uganda.

The rest of the paper is organised into five sections. The next section outlines the quality of the participation framework. Section three describes the data-collection procedures, while section four presents and discusses the results of the study in five points. First, we examine the types of participatory research at the different stages of the research process, from the perspectives of both farmers and researchers. Then we discuss how farmer participation occurred and how the process is managed. The next sections investigate who participates in FRGs and the factors determining farmers' participation in FRGs. The last section discusses FRG performance criteria and highlights farmers' assessments of the impact of FRGs. In conclusion, the paper outlines some issues that need to be considered in improving the quality of participation in FRGs.

ANALYTICAL FRAMEWORK: THE QUALITY OF PARTICIPATION IN PARTICIPATORY RESEARCH

Uphoff (1988) observed that participation, and participatory research, is an overreaching concept best approached by looking at its more specific components or its dimensions. Thus, identifying the critical traits or vital signs of participation should be the basis of evaluation (Uphoff, 1988; Oakley, 1994). The dimensions of participation concern the kinds of participation taking place, who participates in them, and how the process takes place. In this paper we use the term 'quality of participation' in a more general sense to mean special or distinguishing features of the participation process and not in its more normative sense of how good or bad something is. Recently, the CGIAR Systemwide Program on Participatory Research and Gender Analysis (PRGA) developed a framework that distinguishes two components of the quality of participation: the building blocks or dimensions of participation and the management principles of participation (PRGA, 2000). The building blocks represent the analytical variables used to describe participatory research, and ask questions such as:

- What type of participation is involved? When, at what stage of the research, should stakeholders be involved? What is the degree or strength of the participation? What is the objective of participation? How is the participation process managed?
- Who is participating? Who should make key decisions? What roles should the different participants play?
- What are the criteria for successful participation? How do the participants evaluate the process of participation and the results?

The management principles ask the question 'how do we do participatory research?' (Ashby, 1997) and concern methods, skills, and principles in facilitation, reflection, and systematisation of learning processes. They refer to some elements that need to be considered in managing participatory research processes, and some methods and criteria used to determine the appropriateness, effectiveness, and validity of participatory research processes. This paper is concerned with the analysis of the 'building blocks' or dimensions of participation in FRGs. A subsequent paper will present empirical findings on the performance of FRGs and the factors explaining their success or failure in participatory research. The study also aims to test the following hypotheses with respect to the process of participation:

Hypothesis 1: Different types of participation occur at different stages of experimentation in FRGs

Hypothesis 2: Farmers' participation in groups tends to follow a normal adoption curve (Rogers, 1995), rising slowly at first, accelerating to a maximum, and then increasing at gradually slower rates.

Hypothesis 3: Farmers' research groups may exclude certain categories of local people, particularly women and poor farmers, who may not be able to absorb the cost of participation and experimentation. More specifically, we hypothesised that:

- Men tend to dominate community organisations (and therefore FRGs) because they are more likely to have land and other resources for experimentation, and are more likely to be in contact with external (research) organisations.
- Resource-rich farmers are likely to dominate FRGs because they have resources to absorb the cost of participation and of experimentation.
- There are significant positive relationships between a farmer's education level, membership in local organisations, and participation in FRGs.

DATA-COLLECTION METHODS

The empirical study was conducted within two benchmark sites (Rubaya and Kashambya) of the African Highlands Initiative in Kabale, southwestern Uganda. AHI was established in 1995 as an ecoregional programme to develop and implement a participatory R&D programme on natural resource management (NRM) in the intensively cultivated, diverse, and complex highlands of eastern and central Africa. The current programme operates in eight benchmark sites in five countries (Ethiopia, Kenya, Madagascar, Uganda, and Tanzania) and focuses on developing, testing, and adapting technologies and management options, approaches, and methods to foster farmer and community innovations in relation to NRM. AHI's approach emphasises the use and formation of FRGs as a central strategy to participatory research. The Kabale benchmark site is located in the highlands of southwestern Uganda and is characterised by high population densities (456 inhabitants/km²), adequate bimodal rainfall (1000 mm to 1500 mm), numerous catchments with steep cultivated slopes (1900 m to 2400 m above sea level), with severely declining soil fertility, and fragmented and scattered small land holdings. Research is conducted by a multidisciplinary team of scientists from the national agricultural research organisation (NARO) in collaboration with international agricultural research centres (IARCs) and non-governmental organisations (NGOs).

The data come from an empirical study of 21 FRGs using a combination of participatory methods and sample survey questionnaires. Focus-group discussions were conducted with FRG members. Informal and semi-structured interviews were conducted with group leaders and group members as well as non-participating farmers. The analysis was complemented by an econometric analysis of survey questionnaires from a sample of 129 FRG members and 61 non-participating men and women farmers within the communities. The empirical model of factors determining participation in FRGs was estimated by the Logit model using LIMDEP econometric software. The Logit model is a regression technique that has been shown to be appropriate for examining qualitative dependent variables (such as participation) and permits the interpretation of participation as probability (Lia, 1994). It has been extensively used in empirical adoption studies (Polson and Spencer, 1991; CIMMYT, 1993).

RESULTS AND DISCUSSION

Types of participation in FRGs

There exists a large body of literature suggesting various typologies of FPR (Ashby, 1986; Biggs, 1989; Okali et al., 1994; Pretty, 1995; Ashby, 1997; Martin and Sherrington, 1997; Selener, 1997). However, Biggs' classification, based on the different relationships between researchers and farmers, and their decision-making roles at various stages of the research process, is probably the most used. Drawing upon Biggs' classification, Lilja and Ashby (1999) developed a checklist to assess the types of participatory research at different stages of the research process, based on the locus of decision making. The checklist distinguishes three research stages with about 16 activities, and five types of participatory research, depending on who makes the decision at various stages in the innovation process. The five types of FPR are:

- Type A (*contractual*): Scientists make the decision alone without organised communication with farmers, usually contracting farmers to provide land, labour, and other services needed for on-farm research, without involving them in decision making.
- Type B (*consultative*): Scientists make the decision alone but with organised communication with farmers. Scientists consult farmers about their problems, opinions, preferences, and priorities through organised one-way communication, but the decisions are not made with farmers nor are they delegated to farmers.
- Type C (*collaborative*): The decisions are jointly made by farmers and scientists through a two-way organised communication process, with continuous interaction between researchers and farmers, who are seen as partners in the research process.
- Type D (*collegial*): The decisions are made by farmers collectively in a group process or by individual farmers who are involved in organised communication with scientists. Farmers have the major say in running the experiment but may seek advice from scientists who may facilitate the farmers' collective or individual decision making or may have already developed the ability of farmers to make decisions with little outsider involvement. The major emphasis here is on activities designed to increase the ability of farmers to do research and request information and services from formal research and extension organisations.
- Type E (*farmer experimentation*): Farmers make decisions individually or in a group without organised communication with scientists. This concerns research-minded farmers who experiment on their own.

An analysis of the types of participatory research in AHI-Kabale revealed that typically, farmers participated in the stage of technology evaluation and dissemination. We distinguished eight different stages within AHI's participatory agro-ecosystem management (PAM) approach. These included diagnosis, solution identification, trial planning, trial implementation, trial management, monitoring (data collection), data analysis (evaluation), and dissemination. In general, PRA exercises provided starting points for identifying problems by developing problem trees with farmers, which were then used as a basis for identifying and selecting solutions and best-bet technologies that were the most likely entry points. Once the entry points were established, PAM planning workshops were organised to develop participatory research action plans (PRAP). Then scientists designed adaptive research experiments, which were established on farmers' fields, managed by farmers and evaluated to select best-bet options to disseminate. Greater participation of farmers in the entire research process, moving from the consultative to collegial type of participation is a major thrust of AHI.

We hypothesised that different types of participation occurred at the different stages of the experimentation process in FRGs, and that farmers and scientists may have different perceptions of the participatory process. Figure 1 shows the analysis of the types of participation in different stages of the participatory research process from the perspectives of researchers and farmers. Results show some interesting differences between farmers and researchers in their perception of type and degree of participation at the different stages of the experimentation process. For instance, in the diagnostic stage, researchers relied on PRA to identify major problems, and develop problem trees, mapping resources bases, and current farming strategies. However, while researchers indicated that farmers were consulted in identifying and designing solutions, farmers did not recognise their active participation and instead believed that researchers 'brought' solutions ('medicine') to their problems. It appeared that after diagnosing problems with farmers, researchers then identified on-shelf solutions or best-bet solutions to be evaluated by farmers in farmers' fields. Then simple trails were designed by researchers and established with farmers in group experiments to evaluate different varieties of crops and management practices. Similarly, farmers' involvement in data collection and analysis of trial results was rather limited, except in some cases where field visits were organised and informal evaluations carried out without organised communication between farmers and researchers. This points to a lack of a systematic feedback process to scientists and to the research system. However, we observed that in many cases, farmers took some independent initiative in the management of trials in a more collegial mode. In many FRGs, farmers seemed to be keen on taking over control of some stages in the research, often without researchers' knowledge. Dissemination of proven technologies was spontaneous farmer-to-farmer dissemination, without the knowledge or recommendations of the researcher.

Although there are opportunities to give more roles to farmers (such as monitoring, evaluation, trial management), researchers were still using more of a consultative type of participation. These differences in the different roles and responsibilities of researchers and farmers seem to point to a more functional type of participation and a lack of ownership in and responsibility for the process by the farmers. There is a need to

support research teams and farmers in improving the quality of participation, moving from where it is now towards a more collegial approach to build the capacity of farmers and communities to innovate and conduct experiments on their own. It is interesting to note that this figure and the checklist can be used as a monitoring tool to assess the progress and changes made in the degree and intensity of farmers' participation at different points in time.

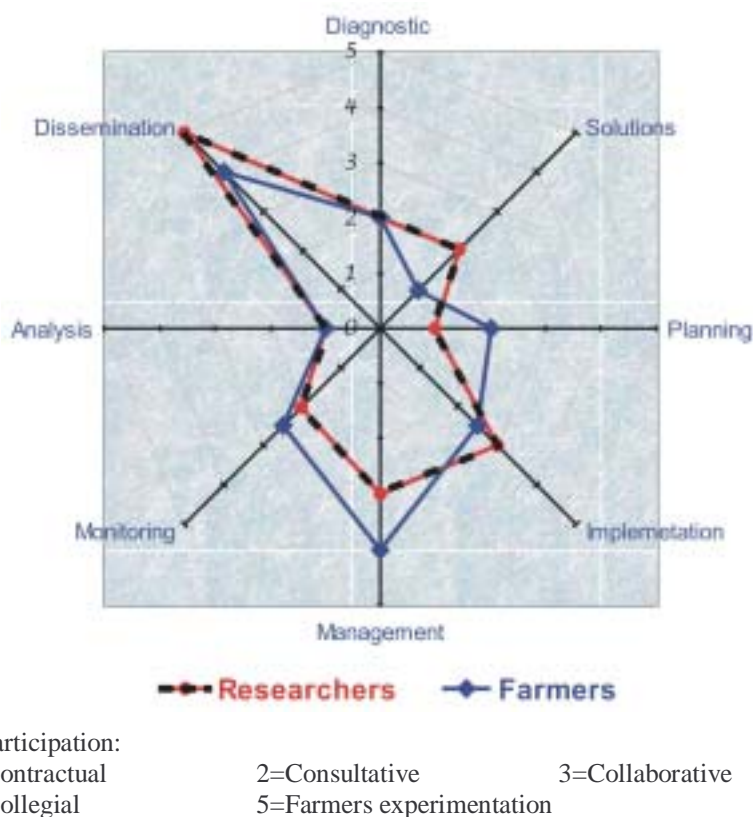


Figure 1. Types of participation in farmer research groups

How does participation occur in FRGs?

The majority of the 21 FRGs in AHI sites were newly formed groups (71%); only 29% were existing groups. Most FRGs were formed between 1998 and 1999, and have conducted three to six seasons of experiments. The average number of farmers in each group was 28, ranging from 10 to 45. FRGs were either mixed (76%) or exclusively women's groups (24%). Most experiments are still on the basics of improved farming methods, testing and evaluation of new varieties, fertiliser application, and other agronomic practices that most farmers did not have prior experience with. Generally, the experiments compare different improved crop varieties and improved agronomic practices to local varieties and local farming methods. Virtually all FRGs have experiments on new varieties of beans and potatoes, the two most important food and cash crops in the area, with some FRGs reaching the stage of seed multiplication for the two crops. Other experiments include testing and evaluation of different varieties of maize, wheat, sorghum, and sweet potatoes. NRM research focuses on soil fertility management and includes experiments on different regimes of inorganic fertiliser application, farmyard manure management, leguminous cover crops, integrated disease management of potato bacterial wilt and bean root rot. These are often conducted on individual plots of group members. However, it is interesting to note that a growing number of FRGs have expressed great interest in agro-forestry technologies, after some exchange visits to both the research station and farmers' fields. In the 2000 season, four FRGs (19%) initiated agro-forestry experiments, starting with tree nurseries, while another FRG already had tree nurseries (eucalyptus and pines).

As noted above, the majority of FRGs were initiated specifically for the purpose of research. Analysis of the FRG formation and development process showed that virtually all have passed the 'storming' stage and reached the 'norming' stage (Pretty et al., 1995) with clear efforts to establish group structures, norms, and regulations. Only a few have reached the 'performing' stage where group members are reaping some of the benefits of participation. In the newly formed FRGs, initial participation was mainly through voluntary self-

selection of farmers based on their interest and willingness to participate in research. Usually, after the initial PAM diagnostic and planning stages, farmers were advised to form groups in order to participate in the research programme. No explicit criteria for membership were laid down, and the scientists were not proactive in facilitating or guiding the selection of members. In contrast to the CIALs, FRG members were not elected by the communities, nor were they conducting research on behalf of the communities.

In line with the different roles of scientists and farmers implied in the different types of participatory research, scientists generally provide technical leadership and supply small quantities of experimental materials (mainly seeds and inorganic fertilisers). In most cases field assistants provide technical training to farmers in experimentation practices and monitor the experiments by collecting data. The research team also has a sociologist who, among other things, facilitates group dynamics and supports FRGs in strengthening their organisational capacity. Experiments are usually planned and conducted by the group on a collective group plot, often donated by one FRG member, or rented out by the group, or in some cases, on individual plots managed by the group. All management of routine experiment activities (land preparation, planting, weeding, harvesting) is carried out collectively on the group plot for two or three seasons, before seeds are shared among individual farmers for further experimentation and for seed multiplication. FRGs are then expected to conduct other rounds of experiments on other technologies, while continuing with informal seed multiplication to sustain both the group and the interest of members in group activities. It is interesting to note that these roles are evolving and in some successful FRGs, farmers are increasingly taking on some of the researchers' roles, and are willing to take on more responsibility.

We analysed trends in participation in the 21 FRGs at different stages of the experimentation process. Our initial hypothesis was that farmers' participation in groups tends to follow a normal adoption curve (Rogers, 1995), rising slowly at first, accelerating to a maximum, and then increasing at gradually slower rates. Results show that farmer participation in FRGs tends, instead, to follow a U-shaped curve (Figure 2), with high participation at the initial stages of the process, followed by a dramatic decrease as many farmers drop out from the groups, and then a slow increase towards the end of the first season. Many farmers participated in the stages of diagnosis and group formation, expecting free handouts (fertilisers, seeds, pesticides, and credit). They later dropped out when they discovered that there were no immediate personal benefits and free handouts. Ashby et al. (2000) also observed that CIALs often go through a difficult period during their early development when the initial enthusiasm of the motivational stage and diagnostic meetings has worn off. Some members lose interest, others drop out. However, after going through this 'storming' period (Pretty et al., 1995), when many members drop out, the FRGs established their group structure by electing a five- to seven-member executive committee and by agreeing on some common rules, norms, and regulations. Towards the end of the first season, when groups harvest their successful experiments, more farmers want to join FRGs. While some groups were inclusive and open to new members, the majority of FRGs established strict norms to restrict new members.

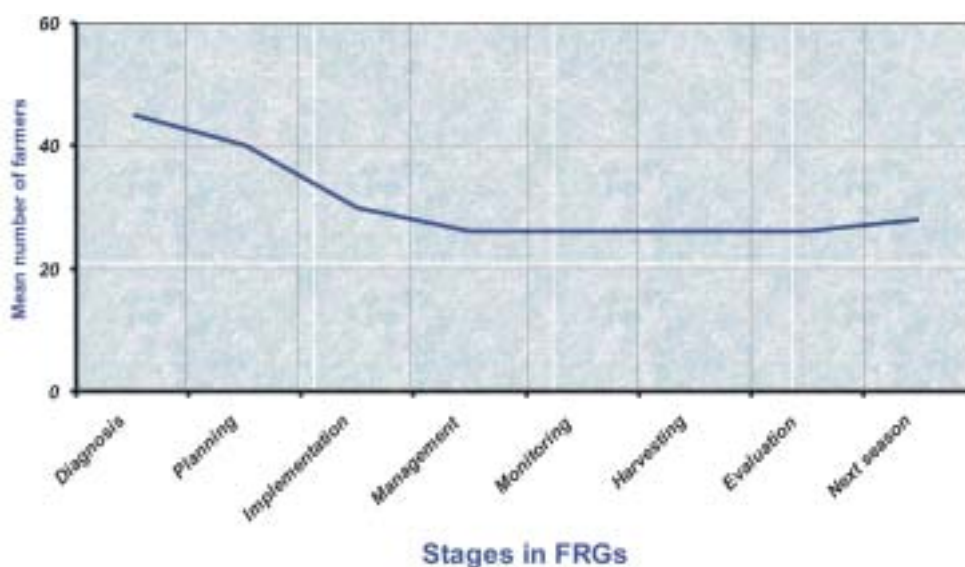


Figure 2. Pattern of participation in farmer research groups

Who participates?

It cannot be assumed that farmers' organisations will represent all groups in the local community (Bebbington et al., 1994). It is thus important to identify the specific characteristics of the participants in order to assess the quality of participation, as it determines who participates and how the process will be managed. Two aspects of who participates need to be clarified in order to interpret the nature (quality) of participation: representation and expertise, i.e., whether the participants are representative of a population of end users and whether the participants bring relevant expertise to the process (Ashby, 1997). Gender and wealth are basic determinants of representation and expertise and need to be used as criteria for distinguishing who participates. We therefore hypothesised that

Farmer research groups may exclude certain categories of local people, particularly women and poor farmers, who may not be able to absorb the cost of participation and experimentation.

Gender

Previous studies on farmers' research organisations have reported significant gender differences in participation. In his study on participatory evaluation of farmers' organisations in Asia, Uphoff (1988) found that membership in farmers' organisations was only about 5% female, and that less than 1% of farmer representatives were women. Similarly, Ashby et al. (2000) reported that the majority of CIALs in Colombia were men-only (56%) while only 7% included women only, and women were in the minority (31%) in mixed CIALs and tended to drop out. In Honduras, specific efforts were necessary to include women, given their rather low representation in CIALs (Humphries et al., 2000). This suggests that women may have less organisational responsibility. We therefore hypothesised that

Men tend to dominate community organisations (and therefore FRGs) because they are more likely to have land and other resources for experimentation and are more likely to be in contact with external (research) organisations.

Results show that there was a significantly higher participation of male farmers at the beginning of the process, compared to women (figure 3). However, as FRGs progressed, the proportion of men decreased while the relative proportion of women increased dramatically. Women represented about 67% of farmers in

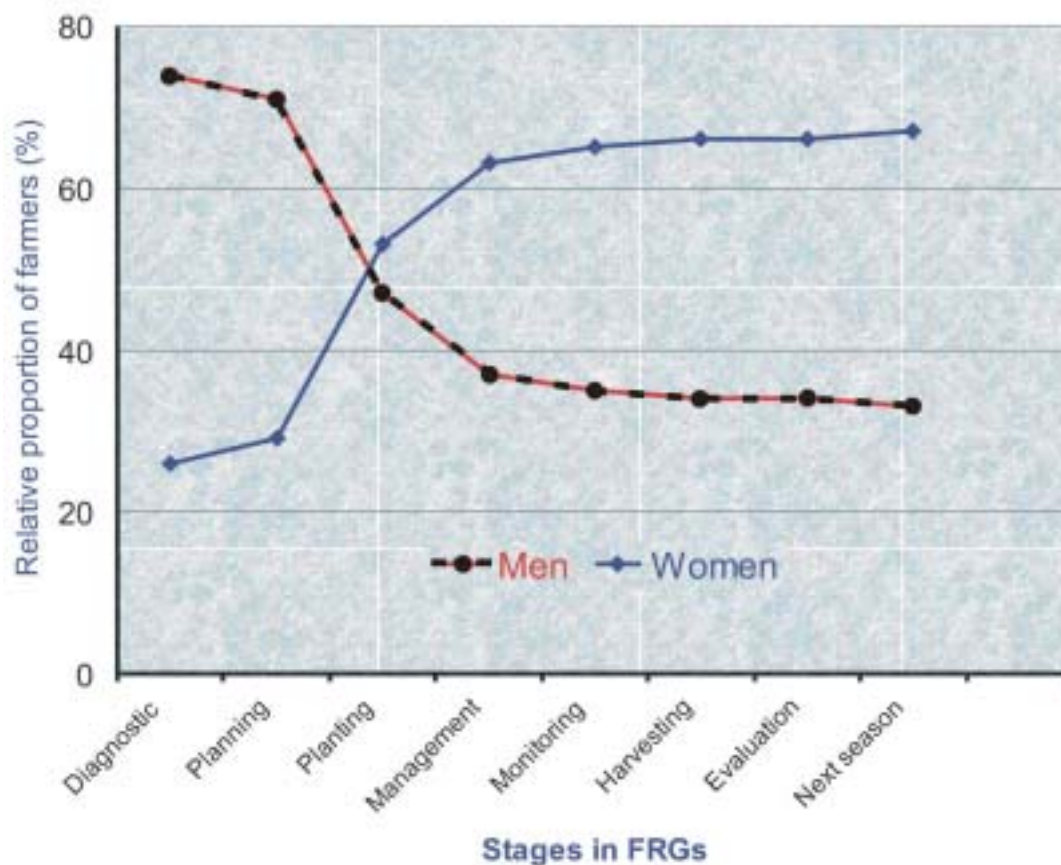


Figure 3. Men and women farmers' participation in FRGs

mixed groups, and 24% of the FRGs were women-only. By contrast, there was no exclusive men's group, and men were reported to have lower participation rates in mixed groups, although they monopolised leadership positions in mixed groups. Analysis of leadership positions in mixed FRGs showed that virtually all chairpersons were men (92%), while the majority of vice-chairpersons were women (55%). Further, FRG secretaries tended to be men (83%) in mixed groups, while women were often assigned the role of treasurer (72%) because of their perceived integrity and reliability in keeping group funds and other assets. In general, we found that men occupied about 62% of positions in the executive committees of mixed FRGs, despite the fact that women constituted the large majority of members.

These gender biases in leadership positions can be explained by persistent gender relations within the household and the community, where men are perceived as more able to make decisions, organise group activities, and maintain discipline within the group. Also, men are better placed to establish contacts with external institutions and to voice their needs and demands. In addition, the majority of women interviewed argued that having some men in the group offers some protection to the women and serves a public relations function within and outside the community. Even in women-only FRGs, it is common to find some men appointed as advisors or patrons to the group. In Zimbabwe, women indicated that it was not necessary to have separate women's groups since their needs were the same as the men's (Jiggins, 2001). However, it is interesting to note that there are important dynamics in mixed groups, with women increasingly taking on leadership positions, often by duplicating men's positions or by creating separate women's activities. Furthermore, some 22% of women argued that men are not reliable and are difficult to work with in a group with collective interests, rather than individual benefits. An early diagnostic survey conducted by AHI (1979b) in Kabale also showed that alcoholism and idleness among men was indeed one of the most important problems constraining agricultural productivity.

The higher participation of women can be explained by their dominant roles and responsibilities in crop production. As in many other parts of sub-Saharan Africa, the feminisation of agriculture (Kaaria and Ashby, 2000) has meant that women are now performing most of the agricultural activities, even those traditionally done by men. Further, groups are known to provide women with a legitimate social space to foster a sense of solidarity and collective action. Several studies conducted by the World Bank in Africa, show that women's groups have proven to be one of the most effective entry points for activities reaching poor households, and among the most effective local-level institutions (World Bank, 1998). Thus, making significant efforts to involve women in research can bring significant returns to research. We argue that FRGs are an effective mechanism to provide women with opportunities to participate in agricultural research and development.

Wealth categories

Similarly to gender, some authors have pointed out the limited capacity of R&D organisations to work with the poorest groups, who tend to select themselves out of activities that demand time, risk, or other commitments (Ashby and Sperling, 1994). Rich farmers are likely to be in contact with researchers and development agents, in contrast to the poor, who have neither the resources nor the time to be involved in research activities, nor are they likely to have the political standing to get themselves elected into groups or committees (Humphries et al., 2000). Thus we hypothesised that

Resource-rich farmers are likely to dominate FRGs because they have resources to absorb the cost of participation and of experimentation.

Table 1 shows the distribution of FRG members by wealth categories. Wealth-ranking exercises based on local, socially defined categories of well-being and interviews with FRG members showed that the majority of FRG members were in the average wealth group (68% compared to 53% in the larger community). Resource-rich farmers (not so poor) represented 18% of FRG members and 21% in the larger communities.

Table 1. Comparison of wealth categories between FRG members and other farmers in the communities (%)

Wealth Categories	FRG Members	Other farmers
Class 1: Resource-rich farmers (Not so poor farmers)	18	21
Class 2: Average farmers	68	53
Class 3: Resources-poor farmers	14	26
Total	100	100

The poor represented 14% in FRGs compared to 26% in larger communities. However, resource-rich farmers and educated farmers dominated leadership positions in FRG committees. It may be argued that there is a risk that participation in FRGs may result in the rich capturing the benefits, to the detriment of the poor. Rich farmers are more likely to retain knowledge and technologies for their own use instead of sharing them with the community (Ashby and Sperling, 1994). There is therefore a real risk in farmer participatory research of creating a privileged group of farmers with access to technology. In Ethiopia, Adamo (2000) found that wealth differences affected levels of participation among farmers, with many of the poor farmers struggling to participate in on-farm trials. It has been argued that working with rich farmers may lead to technologies that are not appropriate to poor farmers, and which may not benefit them (Selener, 1997).

In Kabale, with the exception of the small minority of valley-bottom commercial dairy farmers, often residing in cities, it can be argued that virtually all farmers are small-scale, resource-poor farmers using traditional methods of farming. Although there is some differentiation among this category based on socially and locally defined wealth categories and assets, their production conditions are generally similar, and technologies developed with one category can also benefit the other. On the other hand, varietal evaluation and agronomic practices in relation to soil fertility and soil conservation experiments produce goods that are public goods by nature (Humphries et al., 2000). Thus, there is the chance that working with rich farmers can generate spill-over benefits for poor farmers since some of the technologies, knowledge, skills, inputs, and seeds of improved varieties are likely to find their way to poor farmers through local exchange relationships, local markets, social networks, and even theft of seeds. We found no evidence to support the hypothesis that rich farmers monopolised the benefits and technologies developed within FRGs because poor people also participated in FRGs. Experience with the CIALs has also shown that poor people have successfully participated in research and in conducting experiments (Ashby et al., 2000; Humphries et al., 2000), and that CIALs could also benefit poor farmers.

Determinants of farmer participation in FRGs

It cannot be expected that a single FRG would represent all categories of farmers in a community. In order to determine what categories of farmers were likely to participate in FRGs, and to investigate their characteristics, we conducted a survey of FRG members and other farmers in the community. The results of the Logit model showed that five out of the 11 variables included in the model were significant in explaining farmers' participation in FRGs. These were gender, contact with extension services, availability of family labour, village distance, and household decision-making pattern.

Gender was negative, which confirmed our earlier observations that male farmers have a lower probability of participation than female farmers. Family labour, as measured by household size, was also significant in determining participation in FRGs because the availability of family labour allows farmers to participate in group activities without negatively affecting their individual activities. Also, men with available family labour were more likely to get their wives or children to represent them in some group activities, such as weeding, land preparation, and other collective activities.

The results also revealed that farmers from households where a cooperative, bargaining decision-making pattern prevailed had a higher probability of participation than farmers from households where there was a unitary, single decision-making pattern. The results concerning contact with extension services were expected since many empirical findings have indicated that contact with extension services increases the probability of participation: farmers become more aware of innovations and tend to select themselves for experimenting with innovations. These results could also be explained by a self-selection process through which more risk-averse farmers seek more information. Village access would be related to the fact that farmers living in remote villages were less likely to have contact with external entities, such as researchers, who limit themselves to more accessible villages.

In line with our earlier observations, the results showed no significant differences between FRG members and the rest of the community in their economic and wealth circumstances, suggesting that resource-poor farmers were also involved in FRGs, along with resource-rich farmers. Although positive, the effects of education, farmer's age, and household-head status were not significant in explaining farmers' participation in FRGs. The results concerning membership in local organisations were unexpected, as it is known that farmers belonging to local organisations are more likely to participate and select themselves for new organisations. For example, Humphries et al. (2000) found that the majority of CIAL members had been involved in past projects and served as community leaders or members of local organisations. In Kabale, we

observed that local organisations that could facilitate participation in FRGs were generally non-existent or weak, and it was necessary to form new groups.

Performance criteria and indicators for monitoring and evaluating the effects of FRGs

This section addresses the last questions posed in this paper: What are the criteria for successful participation? How do the participants evaluate the process of participation and the results?

In order to respond to these questions, we initiated a participatory monitoring and evaluation (PM&E) system to involve farmers more actively in tracking changes and sharing results for feedback to research, self-reflection, and critical learning. The detailed results of the PM&E system are reported in a subsequent paper on assessing the performance of FRGs and their success factors. We identified eight major impact categories and facilitated farmers in articulating the performance criteria (indicators) that are necessary for monitoring and evaluating the performance of FRGs. These are (1) activity milestones, (2) technology outputs, (3) the participation process, (4) human capital and sustainability, (5) social capital, (6) reach or dissemination, (7) institutional (research) impact, and (8) ultimate impact.

Activity milestones

These refer to the activities and actions that are normally carried out by FRGs—which FRGs set out to do during a given season or a number of seasons to achieve their objectives and outputs. Farmers were facilitated in developing milestones to plan their activities, monitoring their timely execution, and assessing how well they were executed as criteria of their performance. The milestones also included regular recording of the inputs, resources, and time used to execute the activities and to achieve the outputs. The indicators of the milestones were meant to assess progress: whether the activities were implemented on time, whether the group was effective in achieving its stated objectives and planned activities, and whether the activities led to the expected outputs and outcomes. These included routine activities for implementing and managing their experiment (land preparation, weeding, monitoring, harvesting, etc.), as well as other activities needed to sustain the group (group meetings, training, self-help).

Technology outputs

Technology outputs were more straightforward and concerned the objectives and the expected results of the experiments or the direct outputs of the technology. These involved the farmers' assessment of the performance of the technology under experimentation. The most common themes of FRG experiments have been varietal evaluation and improving soil fertility. New materials are tested and evaluated against local materials, and new methods against local practices which serve as controls. Farmers developed local indicators for monitoring the performance of different technologies under experimentation. These were also combined with scientists' indicators, which farmers could also monitor and record. Not surprisingly, most indicators pointed to general criteria, such as yield, maturity period, disease prevalence, and labour, as well as other technology-specific performance indicators. These varied among different farmers' groups, but in a considerable number of FRGs, we found that most farmers had a monitoring and evaluation system to assess the performance of new varieties and new practices among themselves, compared to local varieties or local practices.

Participation

This can be considered as both a product and an indicator of success, but also a process to meet the goals and objectives of the research (McAllister, 1999). Thus its evaluation concerned the four dimensions of participation and asked questions about the nature, form, basis, intensity of participation, and basic features of the participatory research processes through systematic observations and recordings of the who, what, why, when, and how of participatory research. The process and dimensions of participatory research and the management principles shape the ultimate outcome. Performance indicators also included some tangible indicators, such as the number of farmers with experiments, the roles and responsibilities of farmers, number of farmers attending meetings, number of women, etc.

Human and social capital

Human capital outcomes refer to the skills, knowledge, attitudes, and capacities that individual members have acquired through their participation in FRGs, while social capital is simply defined as the features of social organisations (social networks, social interactions, norms, social thrust) that facilitate coordination and cooperation, and that enable people to act collectively for mutual benefit (Putman, 1993; Woolcock and Narayan, 2000). It encompasses the nature and strength of existing relationships between members and the ability of members to organise themselves for mutual beneficial collective action.

Reach or dissemination

The concept of reach or dissemination refers to the relationship between FRG members and the rest of the community, and is concerned with dissemination of technology and information, knowledge, and skills within FRGs, as well as to non-participating farmers and the rest of the community. *Reach* describes the scope of who is influenced by the research process and by the FRG, and includes equity considerations (McAllister, 1999). It asks for evidence of spill-over effects to other community members, and prospects for the adoption of the technology.

Institutional and ultimate impact

The institutional impact is more directed to the R&D organisations and seeks to capture some of the benefits that scientists and R&D organisations derive by involving farmers in research in terms of the feedback to scientists, changes in research priorities and strategies, use and application of participatory research tools, and attitudes and behaviours of research. Outcomes and impact describe the ultimate impact that can be attributed, at least in part, to participatory research and includes farmers' overall expectations as well as development impact, such as higher incomes and improvements in well-being, schooling of children, and other material signs of life (Sanginga et al., 1999).

However, given that many FRGs are in the early stages of their development and their true impact can only be observed over the long run, we looked at the process as an appropriate focus for participatory monitoring and evaluation. Process outcomes are defined as the impact on human and/or social capital and the feedback to the research process that result from incorporating farmers or other end-users of research into the research process. These are benefits gained by the process of participating in FRGs, while technology outputs are the benefits directly or indirectly derived from the technology under experimentation. Process outcomes can often be observed in the short to medium term, and can often be causally linked to a longer-term impact on technology and welfare, which cannot be observed within a short time (Lilja and Johnson, 2001). Yet attention to process outcomes tends to lag behind the emphasis placed on technology outputs. Preliminary results pointed to some clear indications of impact from FRGs.

First, perhaps the most significant impact of FRGs is their capacity to reach women and the poor: FRGs proved to be an effective means of reaching rural women and the rural poor, who are often neglected by formal research and extension services. Women constituted about 67% of FRG members in mixed groups and also formed separate FRGs without any proactive intervention from researchers. Similarly, resource-poor farmers, who would otherwise be bypassed by conventional approaches, participated in FRGs. Results of focus-group discussions with men and women revealed that FRGs are increasingly contributing to modifying gender relations, roles, and responsibilities, with male members of FRGs becoming increasingly involved in agricultural activities, alongside women, and developing a better appreciation of women's roles. As noted earlier, PRA exercises in Kabale revealed that one of the most important social problems affecting agricultural productivity in Kabale is the 'idleness' of men, to the extent that district ordinances and local by-laws have been put forward to force men to participate in agricultural activities.

Second, the majority of farmers reported significant improvements in human capital, that is, in their capacities, knowledge, attitudes, and skills. Farmers are collectively acquiring new skills and new knowledge, gaining confidence and self-esteem to articulate their opinions and problems in FRGs and in meetings with external organisations. A considerable number of individual farmers have initiated their own experiments on their own fields and helped others establish demonstration plots. Some farmers are now being considered as 'experts' in their communities and are consulted by other farmers for advice on seed production, fertiliser application, and herbicide use. It is important to note that the two last seasons of experiments were badly affected by prolonged drought. Scientists were easily discouraged by the failures of experiments, but farmers were willing to continue with other rounds of experiments. However, so far very little modifications or adaptations have been made by farmers. Instead, some groups have established their own experimental plots where they have made modifications, often without the knowledge of scientists. Farmers have also come to understand the practice of experimentation as a learning process through small plots, and good management practices.

Third, FRGs support mutually beneficial collective action and other important dimensions of social capital, such as exchanging information and knowledge, sharing resources, collective management of resources, community engagement, a spirit of voluntarism, charitable involvement, and local community participation in R&D activities. Recent studies have shown that certain dimensions of social capital, such as group functioning, participation in decision making, and financial and in-kind contributions to groups can generate returns that exceed those of human capital (Burt, 1998) and can contribute significantly to household welfare (Narayan and

Pritchett, 1999). Social capital is in fact the capital of the poor (Woolcock and Narayan, 2000). In this context, FRGs are a resource that women and the poor are using for reducing risks and accessing agricultural technologies, information, and other benefits of collective action. The majority of these FRGs have strengthened their organisational capacity along with their group leadership structure to act collectively, not only in their experiment activities, but increasingly towards other common goods.

Farmers are increasingly arranging rotating group labour exchanges through FRGs, as well as other activities demanding collective action. FRGs are increasingly becoming resources that individual farmers are using to access agricultural technologies, services, and information; to reduce risks, and to coordinate collective action. We found that FRGs are increasingly becoming a vehicle through which farmers are pursuing wider concerns, initiating new activities, organising collective action among members, and extending relationships and linkages with external organisations. New groups have emerged and demanded to be included in AHI.

FRGs have also provided farmers, particularly women, with legitimate social space to widen their social interactions and organise collective action through regular fora and meetings. These FRGs are increasingly taking the lead in catalysing the development process within their communities, and are increasingly making demands on AHI and other R&D organisations. For instance, most FRGs are now demanding agroforestry technologies and more varieties of different crops. Some have initiated crafting activities to generate income, while others have expanded their activities to include local rotating saving and credit schemes. Farmers in Rubaya have established a local bank for the purchase of fertiliser and have mobilised up to Ushs 617,000 (US\$363). Local stockists of fertilisers and pesticides are now organising themselves. With the initiation of exchange visits, FRGs are helping to build 'bridging' social capital by linking FRGs amongst themselves, as well as to other formal and informal R&D organisations.

Recent studies have also shown that social capital is associated with early adoption of innovations by facilitating greater linkages among individuals, social participation, interpersonal connectedness, norms, and networks that enable people to act collectively. We found some evidence of 'learning with spill-over effects' in the sense that technologies (seeds) and skills are gradually shared with other community members through farmer-to-farmer exchanges and seed sales. At the same time, in some FRGs, there is a tendency to exclude non-group members in an attempt to monopolise the benefits (improved varieties), in response to the ridicule from other community members at the initial stages. This behaviour is consistent with the observations of Humphries et al. (2000) that when research yields private benefits (like improved varieties), it may be of interest to farmers to continue excluding others in the community so that they may capture a larger proportion of the benefits. Similarly, Adamo (2000) reported that the dissemination of technologies introduced to FRGs in southern Ethiopia tended to follow kinship and family ties rather than spreading within the community. This observation questions the argument that FRGs help technology to reach many farmers in the community. However, it is too early to make any definite conclusions because most FRGs are relatively recent and we cannot expect benefits to spread into the community to non-FRG members in a short time. Most FRGs are likely to keep privileges their members before sharing outside the group.

We argue that FRGs make the adoption of agricultural technologies more likely because many people evaluate different technologies together, and under different conditions. In the communities with active FRGs, there is now widespread awareness of technological options, and the demand for improved varieties and planting materials has increased. Although no empirical study has been done on adoption of climbing beans and potatoes, there is mounting evidence that climbing beans and improved potato varieties, initially introduced through FRGs, are now widely available in the communities through dynamic farmer-to-farmer dissemination channels. The most striking example is on production of potato seed by farmers. These varieties were initially introduced for evaluation and testing to a limited number of FRGs in 1995, and are now being multiplied, shared, distributed, and sold to other farmers. One FRG member has joined the Uganda National Potato Seed Producer Association (UNSPA) and is now recognised as a producer of certified seed. In season B of 2000, he alone produced 70 bags (7000 kg) of clean potato seed, which was sold to other farmers and to NGOs, which in turn, distributed the seed to other farmers in the communities. His group also produced an additional 850 kg of potato seed. There are also 12 farmers who are experimenting with seed-plot production technologies, and together produced clean seeds of the Victoria variety, which was eventually sold or exchanged with other farmers through local social networks. Similarly, some genotypes of climbing beans were introduced for evaluation with FRGs, and are now available in the communities. All together, the 21 FRGs analyzed in this study represented about 675 farmers who are directly exposed to new technologies, improved varieties, and new farming methods, and who are acquiring new skills and knowledge. Given the prevailing farmer-to-farmer transfer of technologies, there is a high probability that technologies introduced and developed in FRGs are likely to be adopted rapidly by a large number of farmers in the community.

CONCLUSION

This study was conducted against the background of increasing interest in community-based farmer participatory research as an approach to institutionalising and to broadening the impact of participatory research. One of the major strategies of the African Highlands Initiative is to promote community-based participatory research methodologies for research and development by forming and using farmer research groups rather than individual farmers. This paper assessed the quality of participation in FRGs in Kabale, southwestern Uganda. The quality of participation provides a useful analytical framework for investigating the specific characteristics or dimensions of participatory research by looking at what types of participatory research are conducted, who participates in them, how participation is managed, what criteria should be used to monitor and evaluate the performance of FRGs, and what the impact is.

The findings of this study showed that farmer participatory research is a dynamic process and that different types of participation can occur at different stages of the research process. One of the major thrusts of AHI is to move the process towards more collaborative and collegial participation of farmers to foster the farmers' capacity to innovate and experiment with technologies for natural resource management. The results of the study did not support the hypothesis that farmer participatory research excludes certain categories of farmers (particularly women and poor farmers who may not have the resources to absorb the cost of participation). On the contrary, we argue that FRGs are, in fact, effective mechanisms for reaching women and poor farmers, who are by-passed by conventional R&D services. Although different types of participation occurred at different stages of the research process, the results showed that the participation of farmers was evolving toward a more collaborative mode, with farmers increasingly taking on greater roles and responsibilities, gaining confidence, enhancing their human and social capital, and sharing knowledge, skills, and technologies. However, there are still great prospects and good opportunities to enhance the quality of participation in FRGs. This requires important skills, principles, methods, and tools that researchers and farmers need to build together.

As observed by Braun et al., 2000, FRG approaches require and promote a much closer engagement of agricultural R&D institutions with rural communities, building institutional structures and processes for agricultural development. Given the current problems faced by agricultural research in developing countries, we argue that FRGs can help make research more relevant to the needs of small-scale farmers, increase the efficiency of technology development and dissemination, and hasten adoption and the impact of agricultural technologies on the lives of resource-poor farmers. As an approach, FRGs have great potential for catalysing the participation of farmers as partners in R&D activities. This requires significant support and the personal commitment of researchers. It also requires broadening the scope of participatory research from a functional consultative type to a more collegial empowering type, from variety selection to broader research on natural resource management. However, achieving such potential requires skills, capacity, and personal commitment that researchers in Kabale need to internalise. 'The main obstacle in providing farmer participatory research is the research workers themselves' (R. Booth, as quoted in Selener, 1997).

The findings of this study suggest that one of the most important outcomes of FRGs is their ability to strengthen certain dimensions of human and social capital that generate returns in human capabilities; reduce research risks; access knowledge, skills, and technologies; and facilitate mutually beneficial collective action (Uphoff and Mijayaratra, 2000). It is therefore critical to invest in strengthening the organisational capacity of FRGs and to facilitate FRGs to build both 'bonding' and 'bridging' social capital (Woolcock and Narayan 2000; World Bank, 2000) within and between communities and other groups and organisations. One of the great values of such investment is that it lowers researchers' costs of experimentation and builds farmers' networks and confidence to communicate more easily with each other and with R&D organisations. Farmer participatory research should be viewed through the lens of human and social capital, and the assessment of its impact should include its potential effects on human and social capital, its impact on empowering farmers and improving the organisational capacity to conduct research. We concur with Bebbington et al. (1994:28) that 'if we are serious about fostering the external forces to make research organisations client driven rather than research driven, investments will have to be made in developing local farmers' associations'.

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RESEARCHERS LEARN FROM FARMERS! PARTICIPATORY STUDY ON TECHNOLOGY DISSEMINATION, FARMERS' KNOWLEDGE IN PEST MANAGEMENT, AND FARMERS' INFLUENCE ON RESEARCH (POSTER)

Ursula Hollenweger and Daima M. Mkalimoto

ABSTRACT

Effective dissemination of new technologies is the missing link in achieving wider impact. A study on technology dissemination was conducted in six villages in the District of Arumeru, Northern Zone of Tanzania. The villages were chosen to represent the diversity of the region and belong to three agro-ecological zones and two different ethnic groups. Participatory group methods, similar to participatory learning and action (PRA) were used. The participatory approach was effective in establishing good contact with the communities and for collecting basic data about the villages and the sources of change for technologies of different complexity. Conclusions on how to improve dissemination of knowledge-intensive technologies are drawn. Together with the farmers, we did small trials on diverse issues, including new varieties, climbing beans, new drought-tolerant crops, and pest management. The results of two experiments on pest management are presented. One on integrating tactics to manage bean stem maggot shows the benefits of combining tactics. The other, on the use of botanicals for grain storage, demonstrates that alternatives to chemical pesticides exist. All trials combined treatments coming from research as well as from farmers' practices. Farmers appreciated this way of learning and their improved understanding led to a desire to spread the knowledge they had gained to the wider community, and they adapted a research poster for this purpose. The frank relationship between farmers and researchers resulted in mutual trust and sharing of knowledge. Farmers gained experience with experimenting as a way to learn and find solutions to production problems. Researchers learned about local pest-management strategies, which have been effective in scientific testing and will influence future research. Results from a trial using indigenous concoctions to control bean foliage beetles show that these practices are worth investigation in more detail.

RÉSUMÉ

*La diffusion efficace des nouvelles technologies est l'élément qui permet d'accéder à un plus large impact. Une étude sur la diffusion des technologies a été réalisée dans six villages du District d'Arumeru, dans le nord de la Tanzanie. Les villages, choisis afin de représenter la diversité de la région, correspondent à trois zones agro-écologiques et deux groupes ethniques différents. Dans le cadre de groupes, des méthodes participatives similaires au système « Apprentissage et action participatifs » (Participatory learning and action ou PLA) ont été utilisées. Cette approche participative a permis d'établir un bon contact avec les collectivités et de rassembler des données de base sur les villages et les sources de changement en vue de technologies de complexité diverse. Des conclusions ont été tirées sur la façon d'améliorer la diffusion des technologies exigeant de nombreuses connaissances. Avec les cultivateurs, nous avons fait de petits essais portant sur différentes questions, notamment de nouvelles variétés, les haricots volubiles, de nouvelles cultures tolérantes à la sécheresse et la gestion des ravageurs. Les résultats de deux expériences sont présentés. L'une d'entre elle, portant sur les tactiques de lutte intégrée contre la mouche du haricot, montre l'avantage de combiner les tactiques. L'autre, concernant l'utilisation de produits d'origine végétale dans l'entreposage des grains, démontre qu'il existe une alternative aux pesticides chimiques. Tous les essais combinaient les traitements découlant des recherches et les pratiques des cultivateurs. Ces derniers ont apprécié cette façon d'apprendre et la meilleure compréhension des choses ainsi acquise les a incités à diffuser auprès d'un cercle plus large ce qu'ils avaient appris. C'est dans cette optique qu'ils ont adapté une affiche conçue par les chercheurs. La relation ouverte entre cultivateurs et chercheurs a fait naître la confiance réciproque et l'échange de connaissances. Les agriculteurs ont accru leur expérience en apprenant et en trouvant des solutions à leurs problèmes de production par le biais de l'expérimentation. Les chercheurs ont été informés sur des stratégies locales de lutte contre les ravageurs que des essais scientifiques ont validés par la suite et qui influenceront sur la recherche future. Des résultats d'une expérimentation utilisant des concoctions indigènes pour lutter contre *Ootheca* révèlent que ces pratiques gagneraient à être étudiées plus en détails.*

1. PARTICIPATORY STUDY ON TECHNOLOGY DISSEMINATION:

Introduction:

Effective dissemination of new technologies is the missing link in achieving wider impact. This study investigates sources of change for technologies of different complexity.

Method of investigation:

Participatory group methods, similar to PRA (participatory learning and action) were used. The participatory approach was effective in establishing good contact with the communities and for collecting basic data about the villages and the dissemination of technologies.

Site selection:

The study on technology dissemination was conducted in six villages in the District of Arumeru, Northern Zone of Tanzania. The villages were chosen to represent the diversity of the region and belong to three agro-ecological zones and two different ethnic backgrounds (figure 1 and table 1).

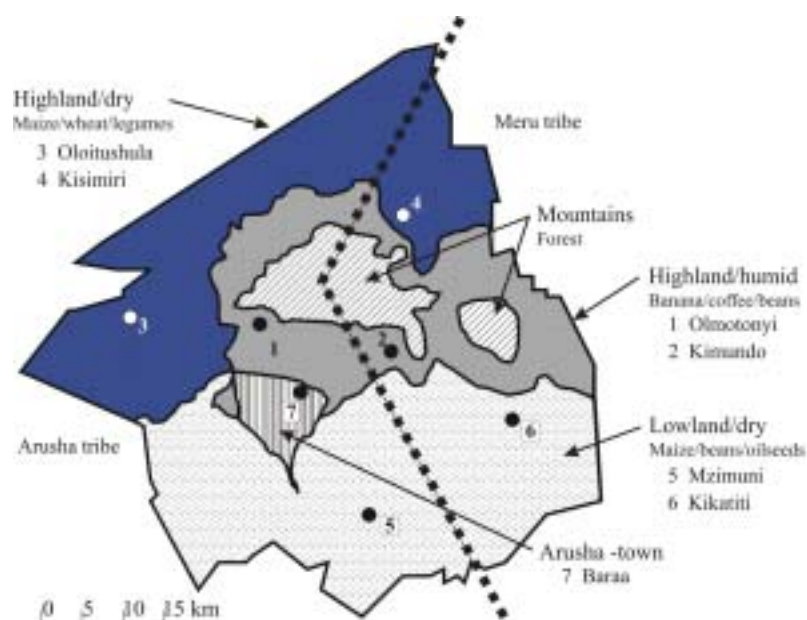


Figure 1. Arumeru District

Table 1. Characteristics of the Selected Villages

Village	Altitude (masl)	Rainfall (mm)	Ethnicity	Population Density	Village Formation
Kikatiti	1000–1200	500–1000	Meru/mixed	70p/km ² 3.5%	Traditional (1950?)
Kimundo	1200–1600	1200–1500	Meru	300 p/km ² 2%	Traditional (1600)
Kisimir	1400–2000	500–800	Meru	30 p/km ² 3%	New (1960) Former estate
Mzimuni	900–1100	400–600	Arusha/mixed	70 p/km ² 3.5%	New (1960?) Former estate
Olmotonyi	1500–1800	800–1200	Arusha	390 p/km ² 2.5%	Traditional (1880)
Oloitushula	1400–1800	500–600	Arusha	70 p/km ² 3.5%	Traditional (1910)

Results:

The sources of many different agricultural changes were identified and then grouped according to their complexity. Table 2 gives details on how many times a certain source for each technology group was mentioned.

- New varieties and new crops (technologies of low complexity) were introduced by many different sources with similar success.
- South African settlers, during colonial times, were the single most-often mentioned source for innovations, mainly for changes in mechanisation.
- The efforts of government organisations (GOs) had a comparative advantage for the introduction of agricultural inputs.
- NGOs did well for high-complexity technologies that require specific knowledge and several changes in the farming system.

Table 2. Technologies Grouped According to Complexity and Source

Group of Technologies	Sources	Cooperatives	Farmers	GOs	Tradition, ITK	Market	NGOs	Settlers	
New varieties of known crops		5		5		4	5	4	23
New crops (coffee, wheat, sunflower...)		1	7	1		1	2	4	16
Industrial inputs, pesticides and fertilisers		1	1	3			1	2	8
Natural inputs (field, storage, organic fertiliser)		1	2	4	5		1	1	14
Mechanisation (animal traction, tractors)								9	9
Intensification and changes in the farming system (zero grazing, soil conservation...)		2	2	3	1		5	3	16
Complexity 1 (varieties and crops)		6	7	6		5	7	8	39
Complexity 2 (industrial and natural inputs)		2	3	7	5		2	3	22
Complexity 3 (mechanisation, intensification)		2	2	3	1		5	12	25

Discussion:

The study found that many factors hinder or contribute to dissemination. Although we do not know the exact processes going on, we can make some general recommendations on how to enhance dissemination of complex technologies among farmers:

- Collaborate with farmers from different backgrounds, so that they will bring the new technology to their relatives and social groups.
- Encourage the village to conduct a field day or a seminar to inform everybody about the new technology and teach them how to use it.
- Stress a good knowledge base on how the technology functions. This will need close contact, maybe with a learning or demonstration plot.
- If possible, and especially for knowledge-intensive technologies, collaborate with NGOs, because they know their clients best and will ensure long-term follow-up on the technologies introduced.
- There are differences among villages: deciding where to start is very important. Choose villages with a variety of people and a history of good collaboration (like share work or communal work).

2. COMBINING FARMERS' AND RESEARCHERS' KNOWLEDGE:

Together with the farmers, we did small trials on diverse issues, including new varieties; climbing beans; new, drought-tolerant crops; and pest management. These trials combined treatments coming from research as well as from farmers' practices. The trial was on control of bean stem maggot (BSM, *Ophiomyia* spp.) with integrated crop management. The second was on improving storage of maize and beans using locally available botanicals. Seeing the differences between the treatments and having learned by doing, the farmers got interested in spreading the acquired knowledge in their area. The dissemination approaches included demonstration plots, community seminars, and leaflets as help for explaining the new technologies to individual farmers.

Farmers learned how to manage small trials and saw it as a way to find solutions to their production problems. They know now what they can expect from research. Researchers learned about different local pest-management practices and got interested in testing them.

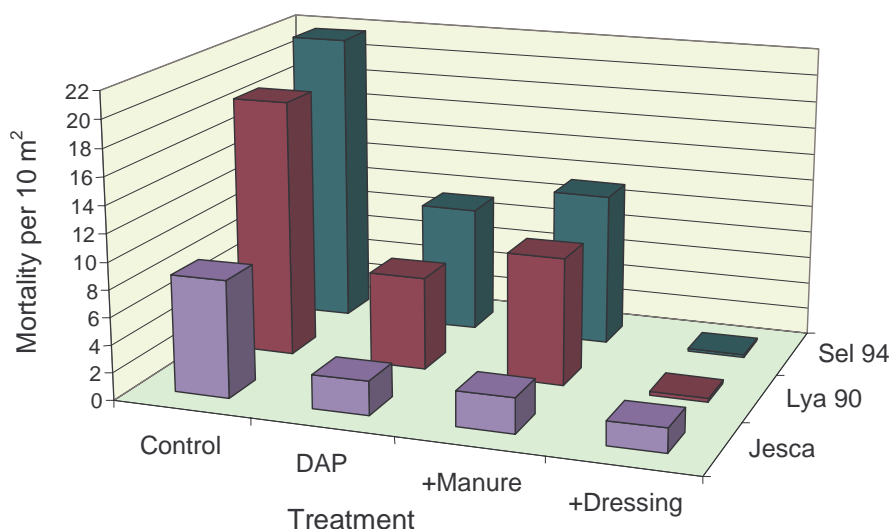
Controlling bean stem maggot (Ophiomyia spp.):

Farmers and researchers identified bean stem maggot as an important pest in bean production. Farmers do not know the lifecycle of the insect and confuse it with ants and root diseases.

Researchers designed the trial using an additive design. All field work and data collection was done together. Results were influenced by a severe drought in one of the three locations.

Farmers learned to understand the lifecycle by observation and decided to write a leaflet that will help them teach other farmers in the village (see the section on 'Farmer-to-farmer dissemination' below).

Fig. 2: Mortality of three varieties under 4 treatments



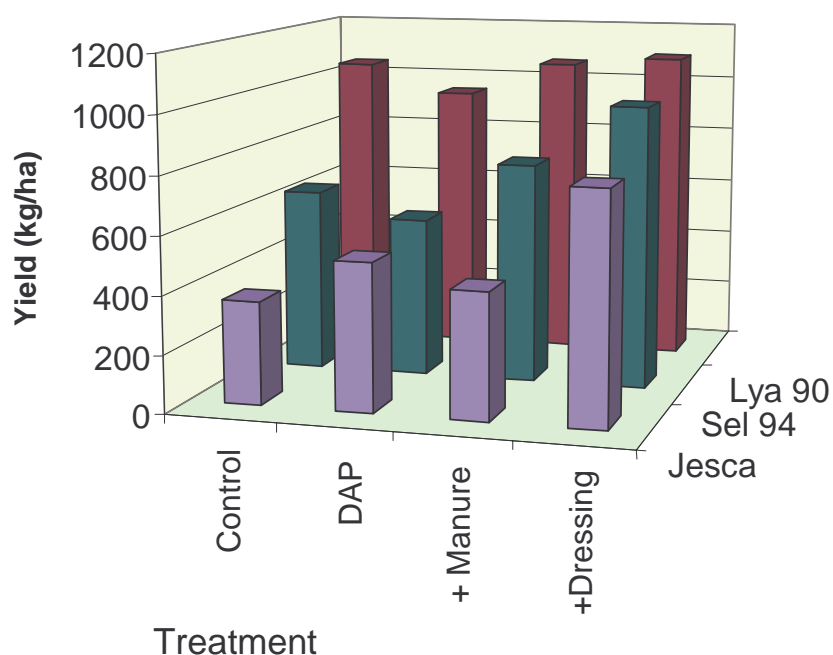
Results:

- There are differences in susceptibility but the reaction to the treatments is the same in all varieties.
- Seed dressing plus fertiliser reduced mortality and increased yield more than any other treatment.
- Fertiliser (DAP and DAP + Manure) reduced mortality significantly.

The results of the statistical analysis with MSTAT (randomised complete-block design with 3 blocks and the 3 varieties considered as replications):

Treatment	Mortality (per 10 m ²)	Yield (kg/ha)
Control	16.39 a	682.2 a
DAP	6.20 b	671.8 a
DAP + Manure	7.72 b	757.2 ab
DAP + Manure + Seed Dressing	0.75 c	958.3 b
LSD (0.05)	4.752	215.7

Fig. 3: Yield of three varieties under 4 treatments



Using locally available botanicals for grain storage:

Traditional storage practices for maize and beans were discussed in a village meeting and farmers interested in participating were selected.

Farmers suggested marigold (*Tagetes minuta*) and cypress leaves (*Cupressus* spp.) as the botanicals they are using. Researchers added wormseed (*Chenopodium* spp.) and neem seed powder to the treatments.

Treatment rates:

Marigold, cypress and neem seed at 1.5 kg/100 kg seed and wormseed at 1 kg/100 kg seed (all dried).

Results:

- Neem: after 4 months damaged seeds below 10%
- Wormseed: after 4 months damaged seeds below 15%
- Cypress: after 4 months damaged seeds below 25%
- Marigold: after 4 months damaged seeds below 30%
- No additives: after 4 months damaged seeds below 50%

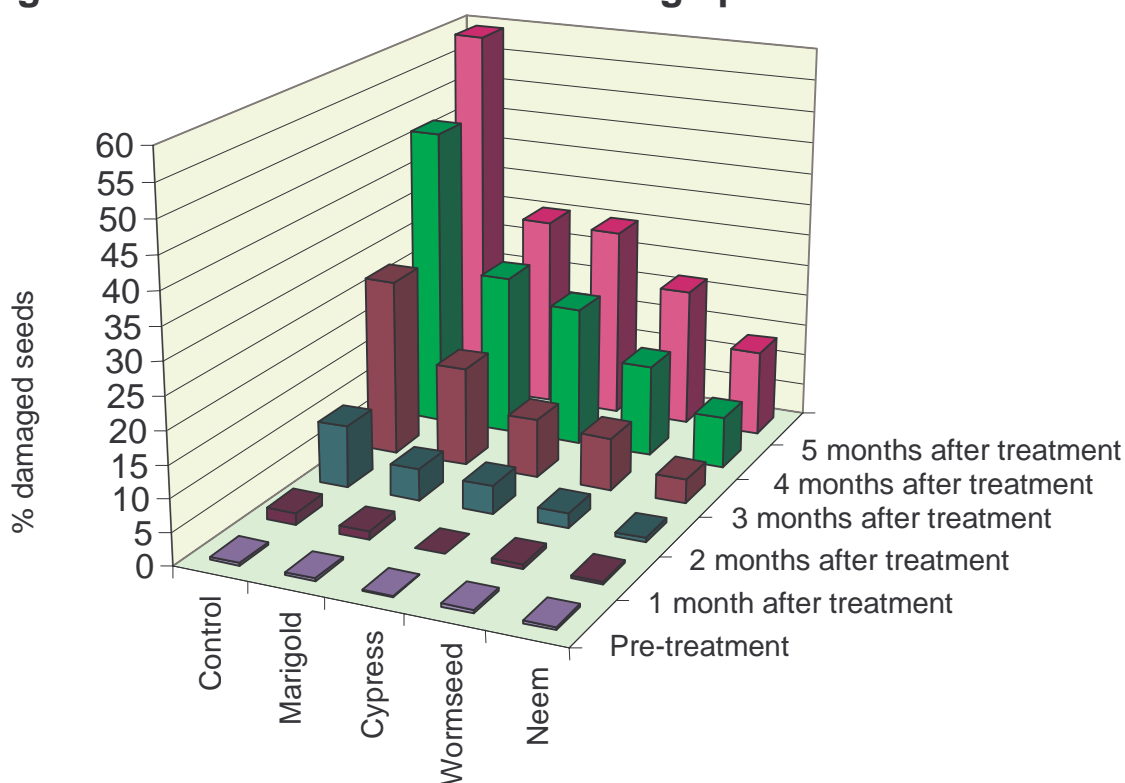
Farmer-to-farmer dissemination

During the initial study, the farmers told us their preferred ways of learning about new technologies: they mentioned workshops, seminars, and field days, but added that they often learn from other farmers during communal or shared labor events and by observation of their fields.

The farmers from Kikatiti considered their experience with the learning plot on BSM so valuable that they decided to write their own leaflet that would help them to teach the management strategies to their fellow farmers.

Starting from the poster that was developed by Dr. J.K.O. Ampofo, together we elaborated a leaflet that the farmers think is easy, understandable, and gives enough information to learn the new practices.

Fig. 4: Effect of botanicals on storage pests over 5 months



3. INFLUENCE ON RESEARCH:

The frank relationship between farmers and researchers resulted in mutual trust and sharing of knowledge with each other.

Farmers explained to researchers some of their traditional methods against insect pests in their fields.

Researchers shared their knowledge about the pests and how they explain the working of the treatments, but wanted to test the farmers' management methods in a scientific way.

Several local treatments coming from two different districts in the Northern Zone were tested on a farmer's field that was heavily infested by bean foliage beetles (BFB, *Oothea* spp.). Figure 7 shows that the indigenous methods work as well as some of the research solutions.

Researchers learned to appreciate farmers' knowledge of pest management and to include it into their research plan for more detailed investigation.

Local treatments to manage *Oothea* infestation:

Farmers in Lushoto district use different botanicals for protecting their crops against insect pests. Mhasha (*Vernonia* spp.) is the one that works best, according to their perception.

Farmers in Arumeru and Hai districts use fermented cow urine (*mkojo*) for the same purposes. They disagree to some extent on the best duration of fermentation: 2 to 14 days are mentioned.

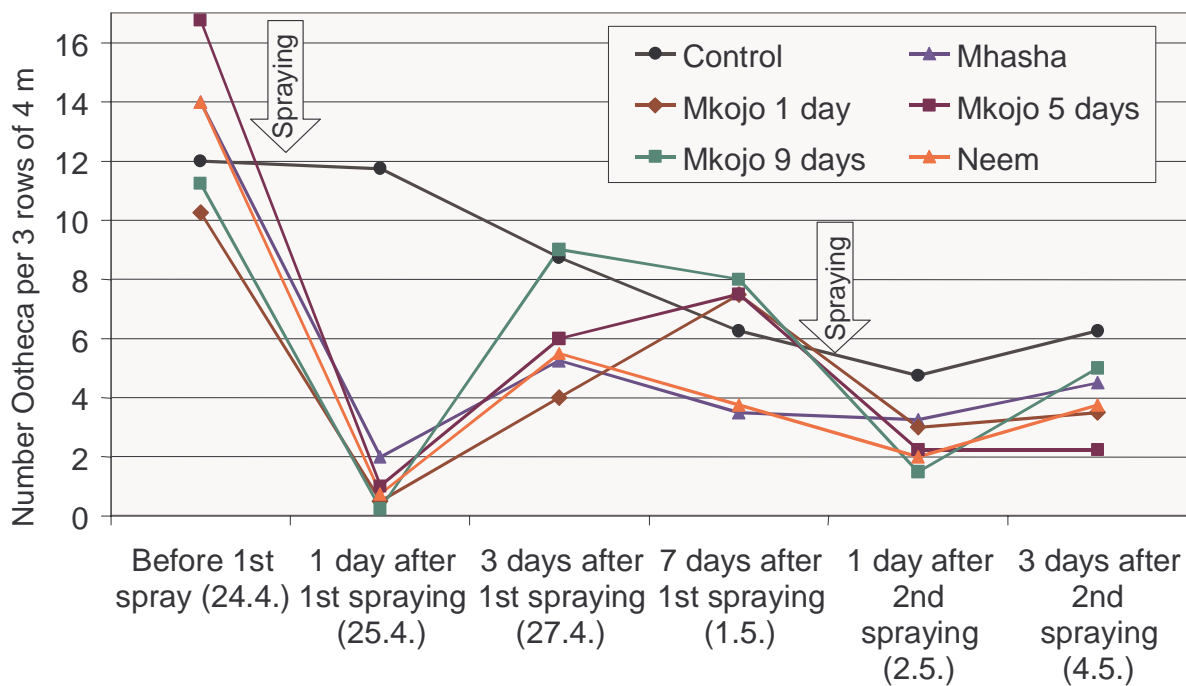
Neem seed oil is a locally available product that has already been tested on several pests and found to give good protection.

Mhasha, three different fermentation stages of cow urine and neem seed oil were prepared as directed by farmers or researchers and applied twice on a heavily infested field in Arusha.

Results:

- All treatments are better than the check (pure water).
- After 3 days the effect starts to wear off (may be due to rain).

Fig. 5: Number of *Ootheca* under 6 treatments



Statistical Analysis:

A statistical analysis was performed with MSTATC for the different dates after treatment. As the general time trend was fewer and fewer insects, the second treatment did not show good significance.

	Mean number of insects per 12 m row											
	day:	0	*	1	*	3	*	7	*	1	*	3
Control	12.0	a	11.8	a	8.8	a	6.3	a	4.8	a	6.3	a
Mhasha	14.0	a	2.0	b	5.3	ab	3.5	a	3.3	ab	4.5	abc
Mkojo 1 day old	10.3	a	0.5	b	4.0	b	7.5	a	3.0	ab	3.5	bc
Mkojo 5 days old	16.8	a	1.0	b	6.0	ab	7.5	a	2.3	ab	2.3	c
Mkojo 9 days old	11.3	a	0.3	b	9.0	a	8.0	a	1.5	b	5.0	abc
Neem seed oil	14.0	a	0.8	b	5.5	ab	3.8	a	2.0	ab	3.8	bc
LSD (0.1)	7.0		3.0		4.3		5.0		3.1		2.3	

*Means followed by the same letter are not significantly different (LSD at $p < .1$)

SESSION 4
ADOPTION AND IMPACT OF NEW BEAN TECHNOLOGIES

IMPACT OF ROOT-ROT RESISTANT BEAN VARIETIES IN WESTERN KENYA: APPLICATION OF IMPACT DIAGRAMMING

Martins Odendo, Soniia David, and Reuben Otsyula

ABSTRACT

In the late 1980s and early 1990s farmers in western Kenya experienced a significant decline in bean production due to root-rot disease, to the extent that in certain areas most farmers stopped growing beans. In response to the crisis, KARI and CIAT introduced, tested, and disseminated several resistant varieties of bush and climbing beans in the Kakamega and Vihiga Districts. Although adoption of the new bean varieties is thought to be high, no systematic study had been conducted to assess their impact or to extract lessons that could improve the design of future research. The purpose of this study was to evaluate the impact of the introduced bean varieties on food security, household income, varietal diversity, and household resource allocations. As a prelude to a formal survey, impact diagramming, which is a farmer participatory tool, was applied to help farmers depict impact. The study involved informal interviews with key informant farmers selected on the basis of wealth status and gender. This paper provides anecdotal evidence of the impact of the varieties using indicators identified by farmers. It shows how impact diagramming can help identify intangible impact, which can be missed in conventional formal surveys, and how it can help resolve the intricate issue of attribution by taking into consideration farmers' views of impact in a participatory fashion.

RÉSUMÉ

À la fin des années 1980 et au début des années 1990, les agriculteurs de l'ouest du Kenya ont connu un déclin important de la production du haricot dû au pourridié, étant même contraints, dans certaines régions, à cesser cette culture. Pour répondre à ce problème, le KARI et le CIAT ont introduit, testé et diffusé dans les districts de Kakamega et Vihiga plusieurs variétés de haricots nains et volubiles résistants à cette maladie. L'adoption de ces nouvelles variétés de haricots semble avoir été assez élevée, mais aucune étude systématique n'a été effectuée pour évaluer son impact ou pour tirer des leçons en vue d'améliorer les recherches futures. La présente étude se proposait donc d'évaluer l'impact des variétés de haricot introduites sur la sécurité alimentaire, les revenus des ménages, la diversité variétale et l'affectation des ressources à partir du point de vue des agriculteurs. Ceux-ci ont décrit les impacts sous forme de dessins schématiques, outil participatif efficace. L'étude comportait des interviews informelles des agriculteurs considérés comme informateurs-clés et se concentrait sur des discussions de groupe autour de thèmes choisis. Les informations de base rassemblées sur les répondants ont permis de comprendre le contexte de référence dans lequel ces impacts étaient évalués. Le présent document fournit des preuves anecdotiques des impacts de l'introduction de nouvelles variétés en s'appuyant sur des indicateurs identifiés par les cultivateurs. Il montre comment la représentation à l'aide de dessins schématiques peut aider à identifier des impacts indirects qui auraient échappé aux enquêtes traditionnelles. Il aide aussi à mieux comprendre la question complexe de la répartition des impacts en prenant en considération le point de vue des agriculteurs de manière participative.

Key words: *Bean varieties, impact, participatory, Kenya*

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INTRODUCTION

The common bean (*Phaseolus vulgaris* L.) is a major staple in the diet of many people, especially the poor in sub-Saharan Africa. Whilst the bean is considered a low-status food—the ‘meat of the poor’—it is the most important source of human dietary protein and the third most important source of dietary calories (after maize and cassava) in eastern and southern Africa (Pachio, 1993). In western Kenya, beans are usually intercropped with maize and are the second most important crop in the Kakamega and Vihiga districts in terms of area grown (Salasya et al., 1998). However, the yield obtained by farmers is low. The average bean yield on farmers' fields in Kenya is about 700 kg/ha when grown in a pure stand and 100 kg/ha to 400 kg/ha when intercropped, compared to over 3000 kg/ha obtained on research stations (KARI/CIAT, 1991). Major constraints contributing to the yield gap can be broadly cited as biotic, abiotic, and socio-economic. Diseases (especially bean root rot), insect pests (particularly bean stem maggot), poor soil conditions, low-yield cultivars, and poor dissemination of technology constrain bean production in Kenya (KARI/CIAT, 1991; Otsyula et al., 1998; Otsyula, Nderitu, and Buruchara, 1998). On-farm yields of new root-rot resistant bean varieties introduced in the Vihiga and Kakamega Districts are 800 kg/ha to 1400 kg/ha when intercropped in maize, compared to 150 kg/ha for the old varieties. In pure stands, the yield is about 1800 kg/ha (Otsyula, *pers. comm.*).

In the late 1980s and early 1990s, farmers in parts of western Kenya experienced a significant decline in bean production due to bean root rot disease, to the extent that in some areas farmers stopped growing beans. The severity of bean root rot in western Kenya, especially in Vihiga and Kakamega, is linked to a decline in soil fertility and a build-up of pathogens from continuous cropping and poor crop nutrition (Nekesa et al., 1998; Otsyula, et al., 1998; Otsyula, Nderitu, and Buruchara, 1998). In response to the root-rot crisis, in 1993 KARI and CIAT, in collaboration with the Kenyan Department of Agriculture, introduced and evaluated several varieties of bush and climbing beans that are resistant to the disease, along with soil management options for integrated control of root rot. The most acceptable bush bean varieties are KK8, KK14, KK15, KK20, and KK22, whilst Umubano, Gisenyi, Flora, Puebla, and Ngwynurare are the climbers.

The most acceptable varieties were disseminated through several channels, notably, a non-governmental organisation (Organic Matter Management Network [OMMN]), farmers (especially women's groups), and the Department of Agriculture (Otsyula et al., 1998a; *pers. comm.*). Although adoption of the new bean varieties is believed to be high, no systematic study has been conducted to assess the adoption and impact of the new varieties. Yet, as IAEG (1999) asserts, in order to account for the public funds they spend, agricultural research organisations worldwide are under increasing pressure to assess the impact of their activities and better integrate social, economic, and environmental considerations in research planning and implementation. CIAT (2000) emphasises that in order to make sure that any research, whether in agriculture or any other domain, is tightly geared to the central development challenges, it must systematically and regularly examine its own impact. Compared to other development projects, Horton and Mackay (1999) report that agricultural research has not entered the mainstream of the literature on impact assessment, despite more than four decades since publication of the first studies of economic impact, and hundreds of impact studies thereafter. Echeverria (1990) provides some reasons for the reluctance of agricultural research managers to undertake impact assessment, including high costs and the opinions of some research managers that benefits are obvious, while others believe that evaluation of research results would produce unfavourable benefit-cost ratios. However, careful *ex post* impact assessment can help scientists to target their work to achieve the greatest payoffs.

Researchers and other professionals who attempt to conduct impact assessments face intractable problems of attribution and accessing adequate baseline data with which to compare changes (IAEG, 1999). To be accountable, one should be able to isolate and attribute impact or results to the activities of research or the resources invested. In research, there is often a long time lag between investment in technology development and the ultimate generation of measurable results. Many groups, institutions, or factors (such as policy changes and new programmes) enter the picture along the way and all of them would like to, or probably can, claim some share of the credit for impact (or the blame if the impact is negative).

The objective of the present study, which is a prelude to a formal impact study, was to obtain farmers' perceptions of the types of impact experienced from the introduction of root-rot resistant bean varieties in the Vihiga District. The information obtained will be used to develop a more focused formal survey using indicators and changes identified by farmers themselves, as well as the reasoning behind them, to complement and supplement researchers' measures of impact.

METHODOLOGY

The study area

This study was conducted in the Sabatia and East Tiriki Divisions of Vihiga District in western Kenya. Vihiga District covers an area of about 521 km² and is one of the smallest districts in Kenya. It lies between longitude 34° 30' and 35° 0' east and latitude 00° and 00° 15' north. With a population of about 499,000 and a density of 958 persons per km², it is one of the most densely populated districts in Kenya. The high population pressure has resulted in high rates of emigration in search of land elsewhere or in search for off-farm employment, especially among men (GOK, 1997; 2000).

The district falls within a relatively high-potential agricultural area, with 90% of its landmass within the high-potential upper midland (UM1) agro-ecological zone and 10% in the lower midland (LM1) zone (Jaetzold and Schmidt, 1983), at an altitude of 1300–1800 meters above sea level. Climate is not a limiting factor to agricultural production. The annual average rainfall is 1800 mm to 2000 mm. The rainfall pattern is bimodal, with peaks in April and August, providing for two cropping seasons per annum. The mean annual temperature is 22° to 29°C.

Agriculture is not only the main economic activity, it also has a social function as it is involved in food security. The main food crops include maize/beans (the staple food), cowpeas, and bananas. Major cash crops are tea, coffee, French beans, and eucalyptus trees. Livestock is mainly zebu cattle, although the numbers of crosses and grade cows are increasing. Other livestock includes sheep, goat, and poultry. Low maize and bean harvests and low milk yields are identified as the major problems affecting farm households.

According to the National Poverty Eradication Plan (1999–2015), poverty is recognised as a major threat to a very significant section of Kenyan households. In 1997, Vihiga District had 54,926 poor households and the total number of poor people was 335,669. Thus, poverty reduction is a major challenge to be addressed in the district. Land pressure is high, making it difficult to overcome income vulnerability; therefore, there is a need to seek interventions to increase productivity and to enhance household subsistence and income-generating opportunities. Diversification of crops, such as the introduction of new bean varieties that are resistant to bean root rot, could be the way to increase agricultural productivity for poor smallholders.

The approaches

Selected participatory rural appraisal (PRA) tools—impact diagramming (ID) in particular—were used to gather information from key informant farmers selected from farmers' groups on the basis of wealth status and gender. Abbot and Guijt (1998) suggest that the sustainable use of a technology can be improved by incorporating farmers' own criteria and perceptions, which are paramount, in monitoring and evaluation schedules. ID is a powerful visual representation of what households or communities perceive as the impact of a given technology. It can be an invaluable tool for unravelling the complexities involved in identifying impact indicators and the attribution (direct and indirect) of impact. Maps and diagrams provide a sense attribution at glance—casual relationships as well as implications. David (2000) demonstrates that ID can be used for early assessments of impacts as well as for casual and intra-household linkages of a technology. However, ID (as with other PRA tools) is susceptible to bias and fashions, and allows collection of mostly qualitative information, which does not stand statistical rigour.

The PRA team (composed of two socio-economists, a plant breeder, and extension agents) explained the diagramming process as explicitly as possible to individual and farmer groups. Farmers were then provided with materials and assisted in sketching diagrams on paper. Literacy was not an important factor in sketching the maps. Whenever severe disputes arose during the focused discussions, concerning a particular feature, further discussions were undertaken to resolve the matter. A checklist was developed and used to help focus discussions with individual and farmer groups. For individual household interviews, background information was collected to provide a baseline for understanding the context within which impact was assessed. When the diagrams were completed, the PRA team took the maps to KARI Station for re-drawing on a computer. These redrawn diagrams were later returned to the farmers or farmer groups for verification and validation.

Table 1. Farmers' Criteria and Impact of New Bean Varieties

Indicators	Variety names					Impact
	KK8	KK14	KK15	KK20	KK22	
Positive						
Early maturity			✓	✓		<ul style="list-style-type: none"> • Saves family in the hunger period • Short hunger period
Good taste			✓			<ul style="list-style-type: none"> • Preferred for household consumption
Cooks fast			✓			<ul style="list-style-type: none"> • Saves time and women's labour to search for fuelwood, less deforestation
High market demand	✓		✓		✓	<ul style="list-style-type: none"> • Quick sales, high prices, and income
Root-rot resistance	✓	✓	✓	✓		<ul style="list-style-type: none"> • High yield
High yield	✓	✓		✓	✓	<ul style="list-style-type: none"> • Food self-sufficiency • Savings because fewer beans purchased • Increased income for purchase of other foods • More beans per meal and more often per week
Swells upon cooking			✓			<ul style="list-style-type: none"> • Family satisfaction • Fewer beans required per cooking
Large seeds	✓	✓		✓		<ul style="list-style-type: none"> • Fewer beans required for cooking
Negative	KK8	KK14	KK15	KK20	KK22	
High demand for fertiliser	✓	✓	✓			<ul style="list-style-type: none"> • Not planted unless fertiliser is available • Planted in fertile fields, if any
Grain susceptible to weevils		✓				<ul style="list-style-type: none"> • Costly to store • Consumed fast
Shatters at maturity		✓	✓			<ul style="list-style-type: none"> • High time and labour required pre- and post harvest
Not good for maize intercrop		✓	✓			<ul style="list-style-type: none"> • Requires sole cropping • Requires change in spacing and pattern of spacing maize
Late maturity		✓			✓	<ul style="list-style-type: none"> • Long hunger periods • More money spend on purchase of beans

Farmers identified both positive and negative impacts from the introduced varieties, the extent of the impact varying with household typologies. The positive impact was improved food self-sufficiency because the beans are used mainly for subsistence.

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ADOPTION OF LYAMUNGU 85 BEAN VARIETY IN THE MEDIUM-ALTITUDE ZONE OF TANZANIA

S. O. Kweka, P. A. Ndakidemi, C. S. Mushi, E. Nkonya, and S. David

ABSTRACT

Common beans are a favourite staple food in Tanzania, providing up to 60% of the protein in rural diets. In its efforts to promote bean productivity in the medium-altitude areas, the Bean Research Programme released five improved bean varieties, including Lyamungu 85 (released in 1985) and Lyamungu 90 (released in 1990). Both are bush bean varieties of Calima seed type. They are high yielding (3594 kg/ha for Lyamungu 90 and 3452 kg/ha for Lyamungu 85), reach physiological maturity in 70–89 days, and are resistant to the major bean diseases found in the mid-altitude areas in Tanzania. Adoption studies for the two varieties were conducted in the Lushoto, Bukoba, Muleba, Karagwe, Babati, Arumeru, Hai, Moshi Rural, and Mbulu districts between 1994 and 1997. Adoption rates varied from district to district. The major reasons for low rates of adoption of both varieties were seed loss due to drought, damage from storage insect pests (a factor not specifically related only to the new varieties), and lack of market.

RÉSUMÉ

Le haricot commun est l'un des aliments de base les plus appréciés en Tanzanie qui fournit jusqu'à 60 % des protéines consommées au sein des communautés rurales. Dans ses efforts pour encourager la productivité du haricot dans les régions de moyenne altitude, le Programme de recherche sur le haricot a introduit 5 variétés améliorées de haricots, dont Lyamungu 85 et Lyamungu 90 (respectivement en 1985 et en 1990), toutes deux étant des variétés de haricots nains, du type de semences Calima. Elles ont un rendement élevé (3594 kg/ha pour Lyamungu 90 et 3452 kg/ha pour Lyamungu 85), atteignent la maturité physiologique entre 70 et 89 jours et sont résistantes aux principales maladies du haricot sévissant dans les régions de moyenne altitude de Tanzanie. Les études sur l'adoption de ces deux variétés ont été menées de 1994 à 1997 à Lushoto, Bukoba, Muleba, Karagwe, Babati, Arumeru, Hai, dans les districts de Moshi Rural et Mbulu. Les taux d'adoption variaient d'un district à l'autre. Les principales raisons des faibles taux d'adoption ou d'abandon des deux variétés étaient les pertes de semences dues à la sécheresse, les dommages causés par les insectes ravageurs sur les produits entreposés (un facteur pas spécialement lié aux nouvelles variétés) ainsi que le manque de marchés.

INTRODUCTION

The common bean (*Phaseolus vulgaris* L.) is the most important grain legume in both production and consumption in Tanzania. The crop is mostly grown in five major zones of Tanzania: Lake, North, East, West and Southern Highlands, with the Lake, North, and Southern Highlands the leading bean-producing areas in the country. The trend in production as well as acreage has been increasing since 1989 (table 1) (Mushi, 1990).

The Northern zone is composed of two administrative regions (Arusha and Kilimanjaro) and occupies an area of 9.6 million hectares (approximately 10.9% of the total area of Tanzania) (Nkonya et al., 1995). The area lies in the moderately cool and moderately warm thermal regime with a mean daily temperature between 15°C–25°C and an altitude of 750–2300 meters above sea level. Northern Tanzania is in the northern rift valley zone with volcanic highlands (Kilimanjaro, Meru, Hanang, and Usambara). On the mountain slopes, dark red soils are predominant with high humus content. The valleys and basins are generally poorly drained and soils are poor in nutrients. The agro-ecologies of the highlands are conducive to bean production. Overall, the northern zone contributes an average of 13% of total bean production (Nkonya et al., 1995).

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Table 1. Annual Bean Production and Area under Cultivation to Beans by Zone, Past Five Years

Zone	Year									
	1983/84		1984/85		1985/86		1986/87		1987/88	
	'000 tons	'000 ha	'000 tons	'000 ha	'000 tons	'000 ha	'000 tons	'000 ha	'000 tons	'000 ha
Lake	62.46	89.22	62.46	89.22	62.46	89.22	62.46	89.22	44.25	85.43
North	51.04	59.65	36.62	65.59	74.13	88.41	73.18	84.61	64.70	102.29
East	19.80	22.17	19.26	22.62	20.78	22.81	20.78	22.81	20.37	20.45
West	13.10	19.40	33.21	41.52	21.60	30.60	21.60	30.60	13.96	19.94
S. Highlands	65.99	61.66	86.11	71.38	83.00	86.35	91.73	81.17	74.11	82.53

Since the early 1980s, research on beans has concentrated on genetic improvement aimed at producing varieties that are resistant to major diseases and insect pests, produce well under infertile soils, have acceptable seed characteristics, etc. This kind of multidisciplinary research has resulted in the release of Uyole 84, Lyamungu 85, Lyamungu 90, Uyole 90, Selian 94, Uyole 96, JESCA, and Selian 97.

A study aimed at determining the adoption of Lyamungu 85 in the Northern and Lake zones of Tanzania was done in 1994 in Lushoto, 1995 in Arumeru and Babati, 1996 in Bukoba, Muleba, and Karagwe, and 1997 in Hai, Moshi Rural, and Mbulu districts. Its objectives being to (1) study the adoption of Lyamungu 85 among small-scale, bean-producing farmers and (2) to evaluate factors influencing adoption or non-adoption of Lyamungu 85.

SEED DISSEMINATION STRATEGY

Lyamungu 85 was released for the mid-altitude zones of Tanzania (1000–1500 m). Originating from CIAT, the main characteristics of Lyamungu 85 are that it is type 1A, red-mottled, large-seeded, matures in 70–89 days, cooks in 49 minutes, and has a yield range of 1000 kg/ha to 3452 kg/ha. Between 1988 and 1993, over 1000 small-scale farmers in Kilimanjaro, Arusha, Kagera, and Shinyanga received Lyamungu 85 seed from the Tanzanian National Phaseolus Bean Program (Ndakidemi et al., 1996). Farmers were supplied with 0.1 kg to 20 kg free of charge on a one-time basis through either participation in on-farm varietal trials or seed distributions carried out by researchers and extension agents.

METHODOLOGY

Two districts (Hai and Moshi Rural) in the Kilimanjaro region and one district (Mbulu) in the Arusha region were sampled, based on their being the major bean producers in Northern Tanzania. These districts were also involved in on-farm variety trials and seed distributions done through the Phaseolus Bean Research Programme in collaboration with the SADC/CIAT Regional Bean Programme. Six villages were sampled from Hai, nine from Moshi Rural, and five from Mbulu. Sample sizes ranged from a low of 2 to a high of 34, with an average of 12 per village and 79 per district. Farmers were randomly sampled from the village list of bean growers.

RESULTS

A total of 237 farmers were interviewed in all three districts: 160 (68%) males and 77 (32%) females. Most of the farmers interviewed were between 31–60 years old and the level of education was generally high (table 2).

Adoption and acquisition of Lyamungu 85

The proportion of farmers who had adopted Lyamungu 85 was highest in Moshi Rural (91%), followed by Hai (87.3%) and Mbulu (73%). The high rate of adoption could be due to the proximity of these districts to Lyamungu and Selian Agriculture Research Institutes, making them more convenient for on-farm variety trials and seed distribution and providing an incentive for adopting the new variety.

Table 2. Demographic Characteristics of Farmers Interviewed

	Hai (N=79)	Moshi Rural (N=76)	Mbulu (N=82)
Gender			
Male	52 (66%)	33 (43%)	75 (91%)
Female	27 (34%)	43 (57%)	7 (9%)
Age			
< 20	0	0	0
21 – 30	8	9	16
31 – 40	26	16	30
41 – 50	31	17	18
51 – 60	10	20	7
> 61	4	14	11
Education			
None (Illiterate)	0	8	7
Basic Primary Ed.	16	17	19
Standard (7/8)	40	33	43
Secondary Ed.	11	5	6
College Education	12	10	4
Adult Education	0	3	3

Fifty-six percent of the farmers in Hai and 61% in Moshi Rural obtained Lyamungu 85 seed from on-farm trials. However, in Mbulu, only 15% obtained their seed through trials, the majority acquiring seed through the market (45%) and from friends/relatives (36%).

Positive and negative traits

Table 3 shows that high yields and palatability were the most important attributes of Lyamungu 85 in all three districts. The high ranking of palatability compared to marketability in Hai and Moshi Rural indicates that Lyamungu 85 is used mainly for home consumption. Marketability was more important in Mbulu than in Hai and Moshi Rural, indicating that the variety is mostly used for income in Mbulu. Earliness was the third most positive trait after palatability and high yield in Moshi Rural, but in general, the most important attributes in all three districts were high yield, palatability, marketability, earliness to maturity, and short cooking time.

Regarding negative aspects and undesirable characteristics, susceptibility to heavy rains (which resulted in lodging) and insect pests were mentioned as most the important negative attributes in all three districts; susceptibility to diseases was mostly reported in Hai.

Table 3. Positive and Negative Traits of Lyamungu 85, Percent Reporting

	Hai (N=79)	Moshi Rural (N=76)	Mbulu (N=82)
Positive traits			
High yields	52	49	75
Marketability	17	12	65
Palatability	46	55	53
Drought resistant	—	—	16
Earliness to maturity	19	46	16
Insect pest resistance	6	10	11
Good for different food types	—	11	15
Fast cooking	32	23	12
Disease resistant	17	7	5
Negative traits			
Susceptible to diseases	11	1	5
Susceptible to insect pests	10	10	7
Susceptible to heavy rains	8	15	15
Low yields	1	1	3
Susceptible to drought	4	6	—

Reasons for not adopting Lyamungu 85

Most farmers who no longer sowed Lyamungu 85 dropped the variety for a number of reasons, the most common being consumption of all seeds in Hai (44%) and Moshi Rural (50%). The other main reason was drought, which was cited mainly by farmers in Moshi Rural (28%) and Mbulu (100%).

Diffusion

The majority of farmers shared seed. Among those who had grown Lyamungu 85, in Hai 97% diffused seeds to other farmers within and outside the district, followed by 75% in both Moshi Rural and Mbulu.

Most of the seeds were given as gifts to relatives, neighbours, and friends or through other organisations (churches). Very little was diffused through selling or exchanging. Lack of requests for seed and small stocks of seed were the only reasons given by farmers (adopters and non-adopters) who did not give seeds to others.

DISCUSSION

The survey showed that there was a higher rate of adoption of Lyamungu 85 in Moshi Rural and Hai districts, where many on-farm trials were conducted, which might have had an effect on the adoption rate in these districts.

This survey also highlighted the importance of bean cultivation in the farming systems of northern Tanzania, clearly indicating that beans play an important role in the household's diet and cash income.

A lack of certified seed, seed shortages, and difficulties associated with storage constrain smallholders from taking advantage of price fluctuations.

Transfer of seeds through gifts was found to be the most common method of dissemination in the area. Due to unreliable formal means of seed supply, the informal channel appears to be the most effective. Previously, seeds of Lyamungu 85 were distributed freely to selected farmers who showed interest. But due to higher production and distribution costs, the operation was not sustainable. Another way of disseminating seed has already been developed whereby farmers buy these seeds from stockists at a reasonable price.

Other studies

Similar studies have been done in Lushoto (Ndakidemi and Mushi, 1994), Arumeru and Babati (Nkonya, 1995), and Bukoba, Muleba, and Karagwe (Mafuru et al., 1996) districts, with the following results:

Lushoto District

A 1994 study covering 47 farmers randomly selected from among seed recipients in Lushoto District showed that two to four seasons after seed distribution, 47% of the surveyed farmers were still sowing Lyamungu 90. Adoption of Lyamungu 85 was lower: 35% of farmers surveyed continued to plant the variety four to six years after seed distribution. The major reason for not adopting—for either variety—was seed loss due to drought (77%), a factor not specifically related to the new variety. Other reasons were lack of market, stopped farming, seed destroyed by bruchids, and ate seed. Despite relatively low recorded adoption rates, two factors suggest high adoption potential in Lushoto District: (1) the varieties are being sold in the market (16 of the 19 vendors interviewed had sold them) and (2) there is considerable farmer-to-farmer diffusion, with 96% of respondents (45 seed recipients) having shared a total of 249 kg of seed of Lyamungu 85/90 with other farmers.

Arumeru and Babati districts

A 1995 survey in Arumeru and Babati districts showed that in villages where there had been seed distributions, 43% of farmers surveyed in Arumeru and 22% in Babati were growing the new variety. However, in villages where no seed had been distributed, adoption was lower: 9% of respondents in Arumeru and 7% in Babati. Higher adoption in Arumeru is explained by market demand for the variety from nearby Arusha.

Bukoba, Muleba, and Karagwe districts

Three years after initial seed distribution, 71% of the 94 farmers interviewed (31% of seed recipients) in these three districts were still growing Lyamungu 85/90. Adoption was highest in Karagwe (96%), next highest in Bukoba (67%), and lowest in Muleba District (57%). One hundred three farmers were given seed of the new varieties by 36 seed recipients, suggesting relatively high diffusion by a few farmers and hence a

likely modest to high adoption rate in the wider farming community. All 19 traders interviewed in nine markets sold Lyamungu 85/90, suggesting high demand for the new varieties.

CONCLUSIONS

The survey has shown that Lyamungu 85 has been accepted by the majority of farmers in Moshi Rural, Hai, and Mbulu districts in northern Tanzania. More than 80% of farmers interviewed are still growing the variety and most of them would like to increase the acreage currently sown to the new variety. This indicated that farmers are eager to adopt new bean varieties.

Seed availability was found to be the main problem for faster diffusion of the new variety. There is a need to promote village-level seed production in order to speed up the availability of newly released varieties.

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NOUVELLES VARIÉTÉS DU HARICOT À L'EST DE LA RÉPUBLIQUE DÉMOCRATIQUE DU CONGO

Njingulula Mumbeya

RÉSUMÉ

Les études menées à l'est de la R.D. Congo ont porté sur 39 nouvelles variétés diffusées par la recherche, au bout de 10 ans. Les résultats obtenus montrent que 17 variétés sur l'ensemble ont été adoptées, soit un taux d'adoption de 41,4 %. Quatre variétés volubiles et 13 variétés naines sont actuellement utilisées aussi bien dans le circuit commercial que dans le système semencier paysan. Quatre critères principaux ont été à la base de la sélection des nouvelles variétés par les paysans : le rendement (18 %), le critère goût et couleur (15 %), la rapidité de cuisson (13 %) et la facilité de commercialisation (10 %). Quant aux sources de semences : les paysans acquièrent la grande partie de leurs semences auprès d'autres cultivateurs, soit au sein de leurs propres localités (22,5 %), soit auprès de paysans de localités voisines, lorsqu'il s'agit d'obtenir certaines variétés spécifiques (19,5 %). Une importante part est également achetée au marché (35,5 %). Les services semenciers n'interviennent qu'à 13 % de l'ensemble.

ABSTRACT

Studies undertaken in the eastern Congo on 39 new bean varieties disseminated over a 10-year period show that 17 varieties have been adopted by farmers and are in use in both peasant seed channels and provincial commercial seed channels. The adoption rate is estimated at 41.4%. Four criteria used by farmers to select new varieties are yield (18%), good taste and colour (15%), cooking time (13%), and easy commercialisation (10%). Concerning sources of seed acquisition, 22.5% of farmers get seed for specific varieties from local farmers in their own community; 19.5% get seed from neighbouring farmers; 35.5% buy seed in the market. Interventions from seed services account for about 13%.

INTRODUCTION

En République Démocratique du Congo, le haricot occupe plus de la moitié de la production des légumineuses à graines (Mbikayi, 1988). En dépit de cette importance, Nkusi (1988) démontre que la production du haricot est largement insuffisante par rapport à la consommation dans la région des Grands Lacs (23 kg contre 40kg/personne/an).

Par ailleurs, selon une étude menée par Bertrand (1985), les besoins monétaires entraînent chez les paysans la vente de vivriers qui, loin de correspondre à des surplus, engendraient un déficit et un déséquilibre alimentaire.

Dans le cas de l'est du Congo démocratique, dans la région habituellement appelée Kivu montagneux, à ce problème viennent s'ajouter une forte explosion démographique (225 hab/km²), l'infertilité des sols et la recrudescence de maladies et insectes (Pyndji, 1988 ; Lunze, 1991).

Bientôt des recherches sont menées dans le cadre du Programme National Légumineuses (PNL) basé à l'INERA-Mulungu, avec pour mission l'augmentation de la production en vue de rétablir l'équilibre alimentaire (INERA, 1999). Forte de cette mission et en face de la dégradation de la productivité du haricot dans la région, la Recherche a intensifié ses travaux sur la sélection généalogique et variétale et sur la diffusion de plusieurs matériels potentiellement performants, notamment, selon Nahinama (1988), l'adaptabilité aux conditions climatiques, la bonne qualité organoleptique, la résistance à certaines maladies locales, la bonne intégration dans les systèmes de culture traditionnels et /ou la plasticité édapho-climatique.

Aujourd'hui, l'heure est au bilan pour constater l'issue qu'ont subie les nouvelles variétés du haricot diffusées par la recherche dans la région, les dix dernières années.

En effet, au cas où elles auront toutes été adoptées selon les potentialités que leur reconnaissait la recherche, et du fait de leur passage aux premières sélections effectuées par les paysans, nous seront à mesure de croire que la recherche aura atteint son objectif. Sinon la non-adoption, ne fût-ce que d'une partie du lot, laisserait croire qu'il existe des zones d'ombre non encore exploitées par la recherche, soit dans les critères de sélection ayant conduit au choix variétal, soit dans les canaux de diffusion utilisés pour rendre populaires les matériels proposés par la recherche. Ceci nous ouvrirait une voie pour nous permettre de découvrir où nous nous sommes trompés, afin de nous ressaisir pour pouvoir continuer notre chemin.

Cependant notons que, les premiers résultats de l'enquête menée au Rwanda sur l'adoption des variétés Kilyumukwe, Ikinimba et G2333 (Sperling *et al.*, 1991), semblent n'avoir satisfait que la moitié des attentes, 51 % des paysans ayant reçu ces matériels les utilisent encore dans leurs champs.

L'étude de l'adoption de nouvelles variétés nous semble être une étape très importante dans l'évaluation de l'impact des travaux de recherche sur le système de culture local. Elle a servi à déterminer les technologies qui ont abouti, les raisons de leur adoption ainsi que celles qui sont à la base du rejet d'autres variétés spécifiques.

Les études décrites ci-dessous ont été réalisées à l'est du Congo démocratique entre 1998 et 2000. Nous avons suivi le sort des 39 variétés du haricot diffusées par la recherche dans le milieu depuis 1990.

MÉTHODOLOGIE

La récolte des données qui nous ont permis de réaliser notre analyse, s'est effectuée en deux temps :

- Premièrement les enquêteurs (1 agronome et 1 socioéconomiste) ont visité 11 marchés ruraux locaux pour inventorier la gamme de ces variétés du haricot existant dans le circuit commercial local. Ces enquêtes se sont déroulées en deux périodes, celle du juillet–août 1998, consécutive à la campagne de récolte et celle de septembre–décembre, relative à la période du semis. Les thèmes principaux comprenaient les variétés dominantes vendues, leurs caractéristiques, leurs noms et leurs origines.
- Deuxièmement nous avons réalisé en équipe interdisciplinaire de l'INERA-Mulungu (7 différentes spécialités de chercheurs), dans le groupement de Bushumba, en octobre 1999, une enquête auprès de 135 agriculteurs afin de fournir des données sur leur pratique de culture de haricot, les variétés cultivées ainsi que leur origine.

Les données de ces enquêtes, combinées à la liste descriptive des différentes variétés diffusées par la recherche, nous ont permis de tirer les conclusions sur l'adoption de nouvelles variétés à l'est du Congo.

RÉSULTATS

Les investigations effectuées dans les exploitations agricoles ainsi que sur l'ensemble des marchés, ont permis d'identifier au total 4 variétés volubiles, notamment Aliya, G2331, VCB81012 et AND 10, et 13 variétés naines et semi-volubiles : Kirundo, Guanajuato, Ubusosera, Muduku3, Rubona5, Nabuni1, Nabuni6, AND657, Nakaja, Nain de Kyondo, Urubonobono, Mafutala, Ituri Matata. Au total nous avons inventorié 17 variétés sur les 39 diffusées par la recherche, soit un taux d'adoption de 41,4 %.

Par ailleurs la gamme de variétés inventoriées dans la région, dans l'ensembles les variétés locales, était constituée de 41 variétés dominantes, pour la plupart cultivées en mélange variétal.

Nous référant aux résultats présentés par la figure 1, nous constatons que l'importance de la gamme dépend essentiellement de l'importance du marché. En effet, plus le marché constitue un centre commercial important, plus il présente une grande diversité variétale, il attire les vendeurs de divers villages environnants, apportant chacun la spécialité de son milieu (cas du marché de Mudaka avec 19 variétés dominantes).

Quant à l'importance de variétés améliorées, nous avons trouvé qu'elle est davantage motivée par la situation du marché par rapport au Centre de recherche de Mulungu. Les marchés qui ont présenté une grande gamme de nouvelles variétés, sont ceux qui se trouvent dans les parages du Centre de recherche, cas du marché de Kavumu avec 7 nouvelles variétés sur l'ensemble de 11 variétés dominantes vendues. Par contre, le marché d'Irhang, situé à 100 km du Centre de recherche et ne subissant pas assez d'influence de celui-ci, présente moins de nouvelles variétés, 3 sur 9 variétés dominantes.

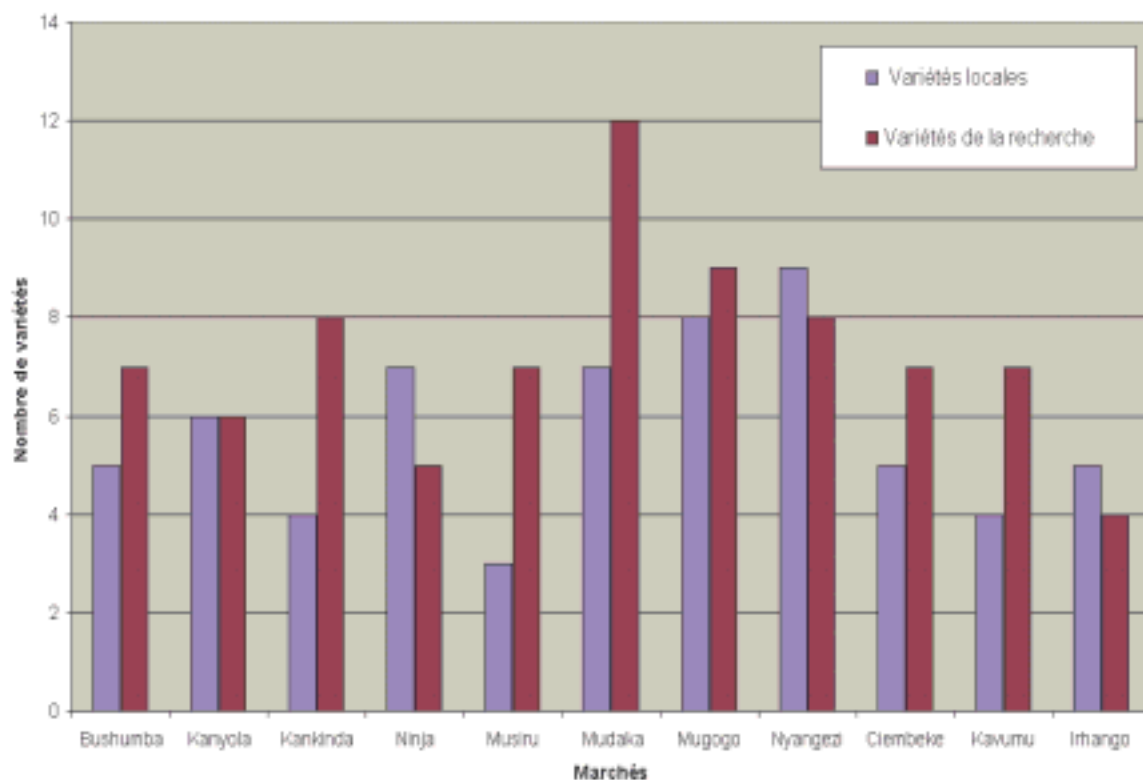


Figure 1. Configuration de type de haricot sur 11 marchés ruraux au Sud-Kivu

Les données présentées dans le tableau 1 nous renseignent qu'il y a principalement quatre sources de semences du haricot.

Pour les agriculteurs paysans du Sud-Kivu, ils acquièrent une grande partie de leur semence auprès des autres agriculteurs, soit au sein de leurs propres localités (chez les parents, amis ou voisins) (19,5 %), soit auprès des agriculteurs de localités voisines, lorsqu'il s'agit de certaines variétés spécifiques (22,5 %). Une part importante est également achetée au marché (35,5 %). Les services semenciers interviennent qu'à 13% de l'ensemble, essentiellement avec les semences améliorées. Puis il y a une autre source non régulière constituée des associations locales de développement qui, par moments recevant de l'aide des structures d'appuis (parfois en haricot), la distribuent aux membres.

Tableau 1. Sources de Semences (%) pour Différentes Catégories de Haricot

Catégories	Agriculteurs		Marché	Service	Autres
	Propre localité	Localités Voisines			
Variétés améliorées	12,5	7,5	13,5	13	2
Variétés locales	7	15	22	—	1
TOTAL	19,5	22,5	35,5	13	4

RENOUVELLEMENT DES SEMENCES

Bien que les paysans du Kivu s'efforcent de conserver leurs propres provisions de semences de haricot aussi longtemps que possible (Elukessu, 1997), ils reconnaissent que les semences de certaines variétés, (suivant leur expression) « se fatiguent » irrémédiablement. Il est rare que les paysans du Kivu renouvellent la totalité de leur stock de semences. Généralement, lorsqu'ils gardent les mêmes variétés, ils les conservent en petites quantités (1 à 3 kg) et éliminent les vieilles semences au fur et à mesure qu'ils multiplient les nouvelles.

Par ailleurs, les nouvelles variétés pour le paysan moyen ne sont pas adoptées pour remplacer d'autres cultures, ils ne tiennent pas non plus à remplacer leur mélange variétal par les nouvelles. Lorsqu'ils le peuvent, ils utilisent les nouvelles variétés pour ajouter un ou plusieurs caractères à ce mélange.

Lorsqu'il s'agit des nouvelles variétés, ils en multiplient en petite quantité pour une surface donnée, puis ils les sélectionnent de façon normale, ce qui revient à dire que le taux de renouvellement est très faible.

CRITÈRES DE SÉLECTION D'UNE VARIÉTÉ

L'enquête sur les raisons pour le choix ou le rejet d'une variété donnée a permis de dégager les résultats suivants :

- les critères déterminants pour la sélection des nouvelles variétés, ont été, le rendement (18 %) suivi de goût et couleur (15 %), ensuite de rapidité de cuisson (13 %), puis de facilité de commercialisation (10 %).
- la majorité des agriculteurs cultivent encore les variétés améliorées qu'ils avaient reçues, pour certains les résultats montrent que l'utilisation diminue avec le temps, c'est-à-dire les agriculteurs perdent petit à petit la variété, quoique hautement appréciée (cas de la variété Aliya). Les raisons qu'ils avancent pour cette disparition des variétés dans les champs sont premièrement relatives aux caractères propres à la variété : non-résistance à la pluie, à la sécheresse et aux maladies.
- D'autres raisons non spécifiques à la variété sont également avancées comme étant les plus importantes : un agriculteur peut cesser de cultiver une variété pour des raisons typiquement socioéconomiques : à cause de la famine, la famille consomme toute la production sans réserver une quantité pour la semence ; ensuite elle manque de possibilités pour renouveler son stock.
- Les charges supplémentaires qu'entraîne l'utilisation de certaines nouvelles variétés jouent parfois à leur défaveur : tuteurage, fumure...

En analysant les données de l'enquête, nous avons trouvé que la durée d'utilisation d'une variété dans le circuit semencier paysan est en corrélation avec le nombre moyen de récepteurs secondaires de la variété par saison : plus elle est distribuée à d'autres utilisateurs, plus elle demeure dans le milieu.

Par ailleurs le processus d'adoption des variétés au Sud-Kivu diffère nettement selon qu'il s'agit de grands ou petits agriculteurs. En effet l'adoption de nouvelles variétés y est motivée soit par l'impact de contraintes extérieures (le marché des semences), soit par l'effet de l'épuisement d'un facteur de production (terre, semence).

Les petits agriculteurs à faible capital mettent généralement plus de temps pour l'adoption de nouvelles variétés : ils trouvent plus sécurisante la complémentarité que leur procure le mélange local, n'adoptent finalement les nouvelles variétés que pour pallier l'épuisement d'un facteur de production. Par contre, les grands agriculteurs motivés par les hautes potentialités de commercialisation qu'offrent les nouvelles variétés (meilleur prix et écoulement rapide) adoptent rapidement les nouvelles variétés proposées par la recherche, à la condition bien entendu qu'elles satisfassent aux critères du marché.

CONCLUSION

Les résultats de l'étude manifestent une adoption partielle de la gamme de variétés proposées par la recherche pour augmenter la productivité du haricot dans le système paysan. Cette étude met en relief un domaine où la recherche devra repenser ses stratégies de diffusion des nouvelles variétés. Quelques variétés que l'on croyait bien appréciées par les paysans ne sont pas restées avec eux aussi longtemps que supposaient les évaluations initiales. Le cas des variétés non adoptées laisse penser qu'il existe quelques points non considérés pendant le processus de sélection ayant conduit aux choix des variétés à diffuser sinon les méthodes de diffusion devront être sérieusement analysées.

Quand nous considérons l'intervention de différentes sources qu'utilisent agriculteurs pour s'approvisionner en semences la recherche devrait également étudier en profondeur la problématique de l'accès de paysans aux semences améliorées. Nous considérons par ce fait que l'implication des agriculteurs dans la production et la diffusion des semences sélectionnées devra être renforcée.

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SESSION 5
INTEGRATED PEST AND DISEASE MANAGEMENT (IPDM)

RESEARCH ON BEAN ROOT ROT IN KENYA

R. M. Otsyula and R. Buruchara

ABSTRACT

This paper summarises the research findings of recent studies on bean root rot in Kenya, where bean production has been constrained by root-rot disease. These studies have covered the etiology and epidemiology of bean root rot, interactions of the root-rot pathogen with soil-borne insects (such as the bean stem maggot), and the relationship between the root-rot pathogen and soil fertility and the moisture content of the soil. In addition, an integrated strategy to control bean root rot has been developed. Future work on the study of the genetics and inheritance of plant resistance to the root-rot pathogen is indicated.

RÉSUMÉ

Le présent document récapitule les résultats des recherches d'études récentes entreprises sur le pourridié du haricot au Kenya où cette maladie entrave la production. Les études ont porté sur l'étiologie et l'épidémiologie du pourridié du haricot et sur les interactions entre l'agent pathogène et les insectes terricoles (comme la mouche du haricot), et le lien entre l'agent pathogène du pourridié et la fertilité du sol ainsi que son taux d'humidité. Une stratégie intégrée de lutte contre le pourridié a également été élaborée. Ce document indique aussi le travail futur portant sur l'étude de la génétique et de l'hérédité de la résistance végétale à l'agent pathogène du pourridié.

Key words: *Phaseolus vulgaris*, resistance, bean root rot, soil fertility, integrated disease management, genetics of inheritance.

INTRODUCTION

Beans (*Phaseolus vulgaris*) are the most important leguminous crop in Kenya and the leading source of dietary protein, (Gitu, 1992; Otsyula et al., 1993). Recently, bean production has been declining in western Kenya (Otsyula, 1994). This is associated with bean root-rot disease caused by a complex of soil-borne fungi, a problem that has been increasing in importance in Africa (CIAT, 1990, 1992, 1993a; Abawi and Pastor-Corrales, 1990). In Central Africa, especially Rwanda, bean root rot became important as early as 1990 (Buruchara and Rusuku, 1992), when it was still ranked low in terms of constraining bean production in Kenya.

Increasing demographic pressure has led to the shortening of fallow periods and continuous cultivation without crop rotation. This system results in a decline in soil fertility and high disease inoculum in the soil (Otsyula, Nderitu, and Rachier, 1998)—the major factors linked with the severity of bean root rot (Buruchara and Rusuku, 1992). Low production, non-existent periods of fallow, low fertiliser inputs, and general use of susceptible bean varieties characterise the areas where bean root rot is a problem.

In western Kenya, bean root rot is primarily caused by *Fusarium solani* spp., *Phaseoli*, *Rhizoctonia solani*, *Sclerotium*, and *Pythium* spp. (Otsyula, 1998), which occur in a complex in the soil and may attack the same plant, causing specific symptoms. They live in the soil and attack the tender root system, often penetrating through the porous root region. *Pythium* causes damping off in young seedlings; the taproot of the affected plant shows lesions and whitish mycelia. *Sclerotium* is recognised by gray water-soaked lesions, which later become brown and extend downwards to the taproot, leading to wilting. *Rhizoctonia* has a reddish brown, sunken canker with clearly defined borders. *Fusarium* is recognised as narrow, longitudinal, reddish brown streaks on the hypocotyl and taproot.

Studies have shown that root rots became severe in areas where bean stem maggot occurs (Nderitu et al., 1996). This is because the root-rot pathogens gain easy entry through the root damage caused by the bean

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stem maggot. Field beans (*P. vulgaris*) are the main host of the bean root-rot pathogens. In western Kenya, root rot is often absent on other common legumes like cowpeas, soybeans, *Dolichos lablab*, *Mucuna*, *Crotolaria*, etc. The pathogens are not internally seed borne but may be carried on contaminated seed, in which case the inoculum levels are often low and disease may not occur.

The pathogens for bean root rot survive in the soil indefinitely in different forms: *Fusarium* as a chlamydoospore, *Sclerotium rolfsii* and *Rhizoctonia solani* as *sclerotia*, and *Phythium* as oögonia. The general field symptoms are damping off at the seedling stage, yellowing of the leaves, stunted growth, and death in severe cases (Otsyula and Ajanga, 1994; Otsyula et al., 1998). There is sometimes complete crop loss in severely infested fields.

CONTROL AND PREVENTION

The ability of bean crops to tolerate root rot is related to the level of soil nutrients, so prevention is effective in environments where soil fertility is good (Otsyula and Ajanga, 1994). Keeping the inoculum level low could also effectively control the disease. This is usually possible in systems where crop rotation is practiced and resistant bean varieties are used (Hall and Phillips, 1992), but in western Kenya, beans are a major food crop and small-scale farmers are reluctant to decrease the frequency of sowing beans on a small piece of land (Otsyula et al., 1998), which makes it difficult to use crop rotation as a practical measure for reducing soil contamination.

Using available information on managing bean root rot, the Regional Research Centre Kakamega, in collaboration with the International Centre for Tropical Agriculture (CIAT), initiated an adaptive research program in 1993 to develop alternatives for integrated management of root rot. The objectives were to identify resistant or tolerant genotypes that were acceptable to farmers and consumers, to evaluate the effectiveness of different cultural practices in the control of root and rot complex, and to study other biotic and abiotic factors that affect the root rot complex.

Cultural methods

Planting on ridges

Planting beans on ridges can be effective in reducing the severity of root rot where soils are not well aerated (Pieczark and Abawi, 1978; Miller and Burke, 1985; Buruchara, 1991; Buruchara and Rusuku, 1992). Hilling up soil around the stem of seedlings encourages the growth of adventitious roots, resulting in tolerance to the disease (expressed as the ability of the plant to recover from attack). Beans were planted on ridges in the Vihiga district of western Kenya to determine the effects on plant mortality from root rot. Results showed that plant mortality was reduced by 70%, with a 20% yield gain (which was lower than when DAP was used, probably because the plants need nutrients for higher production). Planting on ridges is most effective when it is integrated with soil fertility management. It is labour intensive, especially in systems where beans are traditionally not planted on ridges.

Clean seed

Certified seed of a susceptible variety, assumed to be clean and free from root rot inoculum, was planted in hot spots. This was to investigate the possibility that the severity observed in farmers' fields was due to contaminated seed used by farmers. Farmers are known to use seed from their own fields for several planting seasons, which leads to seed contamination, especially by seed-borne pathogens. The results showed that clean seed did not reduce the severity of the disease (Otsyula et al., 1998). It was further evident that the pathogens were not seed borne.

Use of inorganic fertiliser

Fertiliser is known to improve tolerance to bean root rot (Mutitu et al., 1985; CIAT, 1992). DAP (at the rate of 150 kg/ha), TSP (150 kg/ha), urea (87 kg/ha), and KCl (160 kg/ha) were tested against a control in a series of experiments to study their effect on bean root rot. DAP and TSP were effective in improving crop tolerance by lowering plant mortality, encouraging growth of adventitious roots, and improving grain yield. Nitrogen, provided through urea, and potassium, provided through KCl, did not have any effect on control of bean root rot (Otsyula, 1998). An adequate supply of soil nutrients is an important factor in a crop's tolerance to root rot. Otsyula and Ajanga (1994) reported that a high nutrient supply increased growth vigour and resulted in enhancement of plant tolerance to root rot. However, inorganic fertilisers are expensive and not within the reach of resource-poor farmers who form the majority of bean growers.

Use of organic manure

Organic matter forms an important part of the bean-growing environment in the soil. Addition of organic matter to the soil may bring about microbial changes that affect the dynamics of root-rot pathogens (Wortman, C.S. 1994) either through an attack on the pathogen by soil micro-organisms or competition for some essential substrate (Papavizas and Davey, 1960). Green manures (*Sesbania sesban*, *Leuceuna*, *Calliandra*, *Tithonia diversifolia*, and *Clotolaria*), farmyard manure, and compost were tried in a series of experiments to determine their effectiveness in controlling bean root rot. Recommended rates of 10 tons of manure per hectare were used to compare the manures with the control. It was found that crop tolerance was improved by the application of green manures. Plant mortality was reduced by over 40% and yield increased by 50%. The major limitation was availability (Otsyula and Ajanga, 1997; Otsyula et al., 1997; Otsyula and Nderitu, 1998). The recommended rate of 10 ton/ha was high for small-scale farmers. Farmers were encouraged to produce green manures in situ on their farms, but this was not popular as the manure competes against food crops.

Herbaceous legumes (*Mucuna*, *Dolichos lab lab*, *Crotalaria* spp., and *Canavalia*), were introduced as short fallow rotations with maize/bean intercrop or relay crops in the maize. These were meant to maximise space while producing large amounts of manure that could easily be incorporated into the soil during land preparation. The results showed that the herbaceous legumes effectively increased bean yields and at the same time, reduced the severity of the root rot (Otsyula and Ajanga, 1998). Farmers, however, still considered this system as inappropriate because they were losing one season where maize and beans or beans would have been grown.

Cattle manure is commonly found on farmers' fields in western Kenya. Other minor sources of manure are poultry, sheep, and goats. Cattle manure is collected mainly from zero-grazing units, but the amounts are limited due to the small numbers of cattle, resulting in low rates of manure being applied to the fields. The commonly applied rate in the maize/bean fields is one handful of manure per maize hole (2.5 ton/ha). Acland (1986:20–25) recommended of farmyard manure 10 ton/ha for maize, with a minimum recommended rate applied in maize holes of 5 ton/ha (Otsyula and Nderitu, 1998). Farmers either apply the manure directly, pile it up in one spot, or make compost for later use. Farmers tend not to realise the full potential of manure because of poor handling, storage, and application.

Combinations of organic and inorganic manure

Investigation of the combined effects of different organic and inorganic manures on bean root rot severity was done in western Kenya (Otsyula and Ajanga, 1998). The objectives were to determine the effect of inorganic/organic fertiliser on root rot and to assess the socio-economic acceptability of organic and inorganic sources of phosphorus (P). The treatments compared were application of phosphorus (TSP) 25 kg/ha as P₂O₅, *Tithonia* at the rate of 5 tons dry matter per hectare, phosphorus (TSP) applied at 12.5 kg/ha, P₂O₅ + *Tithonia* at 5 ton/ha, *Tithonia* applied at 10 ton/ha, and a control where no soil amendment was used. Results showed that *Tithonia* applied at the rate of 10 ton/ha gave a yield increase of 700 kg/ha and *Tithonia* applied at 5 tons per hectare in combination with a half rate of DAP (75 kg) gave 400 kg over the control. This was the same as when *Tithonia* was applied at 5 tons in combination with half the recommended rate of TSP (25 kg of P₂O₅). There were no significant differences between the various soil treatments on plant survival but all were better than the control—all resulted in better plant survival and yield increase. Farmers preferred the combinations because they were cost effective.

Time of planting

A participatory rural analysis was conducted in Vihiga division in 1996 to identify and diagnose bean root rot. It was found that farmers were able to identify the root-rot problem in their fields, but they attributed it to such factors as witchcraft, dry spells, high rainfall, early planting, and late planting (Nderitu and Otsyula, 1997). The extension and research were unable to differentiate the effects of bean root rot and bean stem maggot where both constraints occurred especially in late planted crop. Trials on effects of planting time, severity of bean root rot and bean stem maggot were conducted in 1997 (Otsyula and Nderitu, 1997). Data showed no direct correlation between time of planting and the severity of the root rot. *Phythium* tended to occur on crops grown when there was high rainfall in a season, while the severity of *Rhizoctonia*, *Sclerotium*, and *Fusarium* did not depend on the moisture status of the soil. This may be because the *Phythium* oöspores require soil water to swim to infection sites. The incidence of bean stem maggot (BSM) was higher on crops grown four weeks after the onset of rain, but the moisture content in the soil did not affect the severity of BSM infestation, which may have been related to the time needed for the insect population to build up. The conclusion was that planting time cannot be used to prevent bean root rot.

Chemical control

Seed treatment with a fungicide (Benlate) was tried in experiments at Regional Research Centre Kakamega. Benlate (28 g per kilo seed per hectare) was used before planting on a susceptible variety GLP-2. Plant survival—used as a measure of severity in the experiments—was reduced by over 90%. Taproot lesion scores were no different from the control (100%) (Otsyula and Ajanga, 1994; Otsyula and Nderitu, 1995). The fungicide is specific for a fungal species and the time it occurs in the field (Eric et al., 1997), but where the pathogen occurs in a complex, a single fungicide might not be effective. This could be why Benlate was not effective in this experiment.

Plant host resistance

Selection of resistant varieties

Breeding for disease resistance has been identified as the main hope for controlling diseases in resource-poor developing countries. Bean varieties have shown host plant resistance to several fungal pathogens, but in Africa, since bean root rot was not severe in the past, sources of resistance were not identified early on. GLP-2, GLP-24, GLP-1004, GLP-585, and GLP-X92 were released in Kenya in the seventies when bean root rot was not a disease of any economic importance, and none of these varieties have resistance to the disease.

In 1992, CIAT-Rwanda initiated a series of screening trials to identify sources of the root-rot complex. The regional bean root-rot nursery was constituted with materials contributed from Rwanda, Burundi, Zaire, and Uganda. These programs were screening bean germplasm against different constraints such as acidic soils, leaf diseases, angular leaf spot, common bean mosaic virus and rust, and bean stem maggot. Twenty-six entries suitable for areas infested with root rot were identified from the regional nursery (table 1) and introduced in Kenya in 1993 short rains. They were tested alongside 374 collections from the Kenya germplasm core collection in root-rot hot spots (Otsyula et al., 1994)—screened for resistance and tolerance based on root-rot rating and bean yield. Ratings were percent of hypocotyl with visible lesions below ground level. Results identified 10 resistant lines (10% of taproot covered with lesions) and six tolerant ones (10%–30% of taproot covered with lesions) from the original 400 entries after two seasons of evaluation (Otsyula et al., 1994; 1998). Of the 374 local accessions, only GLP-X92 was found tolerant. Many introductions found to be resistant to root rot in Rwanda were also found to be resistant in Kenya. Resistant types represented a wide range of seed colour, growth habit, and time to maturity (table 1).

Farmer participatory evaluation of root-rot resistant varieties

Ten resistant varieties—nine introductions and one local variety (GLP-X92)—were given to farmers for on-farm farmer evaluation and selection. RWR-1059 was not included in farmer evaluations because of its lower yield potential, yielding less than the local check (GLP-X92) in trials. Farmer evaluations were participatory, involving 30 farmers in the Vokoli sub-location of Vihiga District. The objective of the evaluation was to expose the farmers to a large number of resistant varieties and at the same time generate information about the varieties that could help in making future decisions. Farmers were requested to evaluate the varieties from 1995 to 1998, based on their own criteria. Farmer evaluations were done in the 1998 long rain by extension agents, researchers, and NGOs. Farmers ranked their selection criteria in the following order: high yield, resistant to bean root rot, maturity period, market price, seed taste, cooking time, seed colour, and seed size (table 2).

Scam-80cm/15 was the most preferred by farmers and best for market, followed by MLB49-89A, RWR-719, and RWR-1092. Red haricot types are popular in the local markets, and farmers identified RWR-719 as a perfect substitution for the susceptible red haricot GLP 585. Farmers pointed out, however, that the variety is late maturing, which is a disadvantage, especially in hunger-prone areas. MLB49-89, though black in seed colour, thrilled farmers because of its early maturity, large seed size, ease in cooking, good taste, and high yield—all of which are very important for resource-poor subsistence farmers.

Selected bean varieties were multiplied and seed distributed to other parts of Kenya, notably the southwestern highlands of Kisii, central highlands-Embu area, and north Rift-Trans Nzoia District. Within western Kenya, seed was distributed to extension services and NGOs working in the area. Other projects have used the information from farmer evaluations to distribute suitable varieties to farmers, such as Farm Level Applied Research in East and Southern Africa (FARMESA) in the Ileho Division and the African Highlands Initiative (AHI) in the Emuhaya Division of western Kenya (Otsyula et al., 2000; Otsyula, 1999). It is estimated that over 5,000 farmers in western Kenya have received the seed of the new root-rot resistant bean varieties, which have been widely adopted. An impact study is underway to determine the effect of the new bean varieties on the resource-poor people of western Kenya (Odeno et al., 2001).

Table 1. Reaction to Bean Root Rot of 26 Bean Introductions from the Regional Root-Rot Nursery

	Name	Colour	Maturation	RX.BRR*
1.	IHUMURE	Grey	Medium	R
2.	MCD 221	Rose coco type	Medium	S
3.	36-89A	Zebra	Medium	S
4.	PEVEYA	Rose coco type	Medium	S
5.	MLB-22-88B	Rose coco type	Medium	T
6.	MLB-69-88A	Zebra	Medium	S
7.	MLB-17-89A	Rose coco type	Early	S
8.	SCAM-80-CM5	Rose coco type	Early	R
9.	SCAM-80-CM15	Rose coco type	Early	T
10.	MLB-48-89A	Grey (small)	Late	R
11.	RWR-1058	Rose coco type (small)	Medium	T
12.	RWR-1059	Rose coco type (small)	Early	R
13.	MLB-39-89B	Chocolate yellow	Medium	R
14.	MLB-40-89A	Chocolate yellow	Late	R
15.	MLB-49-89A	Black	Early	R
16.	MLB-10-89B	Rose coco type	Medium	T
17.	MORE-90019	GLP X92 type	Medium	S
18.	A - 300	Grey (small)	Late	T
19.	RWR-1091	Rose coco type	Medium	T
20.	RWR-1092	Canadian Wonder type	Early	R
21.	RWR-432	Rose coco type	Medium	R
22.	RWR-719	Red haricot type	Late	R
23.	RWR-866	Rose coco type	Medium	S
24.	RWR-221	Grey	Medium	S
25.	RWR-217	Canadian type	Early	S
26.	URUGEZI	Canadian Wonder type	Early	S

* RX.BRR = Reaction to bean root rot: R= Resistant, T= Tolerant, S = Susceptible.

Breeding for resistance to multiple constraints: bean root rot, bean stem maggot, and low soil phosphorus

The complex of bean root rot, BSM, and low soil phosphorus (LP) has been identified as the main constraint to bean production in western Kenya (Otsyula, 1995). Known to occur under same the conditions in farmers' fields, BSM, root rot, and problems with low soil fertility are magnified by the intensification of bean production in high-population areas of the African highlands (Letourneau, 1994; Pachico, 1993). Independent studies have shown that there is sufficient varietal variability to be used for selection of resistance to this complex (Otsyula et al., 1998), but this variability has been identified independently. A screening nursery was established in western Kenya to identify bean varieties resistant to multiple stresses for control of bean root rot and BSM adapted to the conditions of low soil fertility in the region. Ten varieties were contributed from each stress nursery (root rot, BSM, and LP) and were used to constitute a nursery for multiple stress resistance. Preliminary data indicated that RWR-719, MLB-49-89A, MLB-48- 89A, and RWR-1092 from the root-rot resistant source were also resistant to BSM and LP. EXL-158 (resistant to BSM) was also resistant to LP and root rot, while RWK-5, known to be adapted under LP conditions, had good resistance levels to BSM and root rot. MLB-40-89A and XAN-97 showed reasonable tolerance when subjected to all stresses (Otsyula et al., 1998).

Table 2. Farmer's Varietal Selection and Selection Criteria for High-Yielding Root-Rot Resistant Bean Varieties

Criteria	Varieties									
	Ihumure	Scam 80cm/15	MLB-48- 89A	RWR- 1059	MLB-40- 89A	MLB-49- 89A	RWR- 1092	RWR-432	RWR-719	GLP-X92
Yield 8	1	8	1	6	7	9	4	5	10	3
BRR 7	6	8	4	6	10	2	2	4	10	1
Maturity 6	5	3	3	5	1	9	9	5	2	9
Market 5	1	7	7	7	4	2	5	7	6	2
Taste 4	1	7	2	2	8	10	2	2	8	1
Cooking time 3	1	7	1	7	3	9	6	3	3	10
Colour 2	2	6	6	6	4	1	5	6	5	3
Size 1	1	7	5	5	2	9	9	7	2	4
Total	18	53	29	34	39	51	42	39	46	33
Rank	10	1	9	7	5	2	4	5	3	8

Introduction of climbing beans

Climbing beans were introduced in Kenya for several reasons: climbers are tolerant to root rot, have high yield potential (Otsyula et al., 1994), and need less space because of their climbing growth and efficient use of scarce resources, e.g., compost, farmyard manure, and green manure. When grown on small plots, climbing beans yield as much as 100 pods per plant. Six climbing bean varieties (Umbano, Flora, Gwinurare, Puebla, Vuninkingi, and Gisenyi) were introduced in western Kenya and evaluated for performance and acceptability in a predominantly maize-based system. They were found to be suitable for the highlands of Kenya. Umbano was recorded as yielding 4 t/ha (Otsyula et al., 1994). While preliminary evaluation of adoption indicated that climbing beans are favourable for small-scale farms (Otsyula, 1995), most farmers indicated that staking is a major constraint with climbing beans.

Integrated Control for Bean Root Rot

The selection and integration of control measures depend on the combination of opportunities available, the economic status of the farmer, and access to resources. Several experiments have been conducted to identify suitable combinations of technology for integrated control of bean root rot. Otsyula, Nderitu, and Rachier (1998) demonstrated that the most effective way to control bean root rot was with a combination of resistance and soil improvements. The use of green manure and farmyard manure enhanced crop tolerance to root rot. Improving soil fertility and using resistant varieties will reduce the pathogen inoculum in the soil while maintaining natural resources. The limitation is that resource-poor farmers often depend only on the easily affordable technology, which, in this case, is resistant varieties.

CONCLUSION

There are methodologies in Kenya for the control and management root-rot disease in beans. Cultural controls have been well researched and different options recommended to farmers. Sources of resistance have been identified and some varieties adopted by farmers. These recommendations may, however, need further refinement. Incorporating resistance in the existing market classes (GLP 2, GLP 585, and GLP24) is necessary to keep farmers' production market oriented. Technologies like marker-assisted selection for the transfer of resistant genes to market classes is recommended.

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ASSESSMENT OF GRAIN YIELD LOSSES CAUSED BY FOLIAR FUNGAL AND BACTERIAL DISEASES IN PROMISING NEW GENOTYPES OF THE COMMON BEAN IN MALAWI

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ABSTRACT

This paper looks at data obtained from trials to assess grain yield losses caused by foliar fungal and bacterial diseases in the common bean. These trials were conducted in Malawi in 1998/99 and 1999/2000 and showed that most of the promising new bean genotypes were suitable for production by the farming community. Control of foliar fungal diseases, such as angular leaf spot (ALS) with chlorothalonil, led to higher increases in grain yield than the control of foliar bacterial disease, such as common bacterial blight (CBB). The judicious use of chlorothalonil could be an important option in production strategies for the common bean, especially in areas like Bembeke, where foliar fungal diseases such as ALS are a serious problem in every cropping season. Common-bean genotypes like LSA 191 have consistently produced low scores for CBB at Bembeke, indicating that this genotype could be resistant and therefore a suitable candidate for developing integrated disease management (IDM) strategies for control of CBB and also for use in breeding programmes. More efforts need to be devoted to the development of new common-bean genotypes that would be suitable for incorporation in IDM strategies for the control of CBB, which drastically reduces yields and is considered the most important disease of the common bean in Malawi.

RÉSUMÉ

Le présent document examine les données obtenues à partir des expérimentations destinées à évaluer les pertes de rendement des graines provoquées par les maladies foliaires fongiques et bactériennes du haricot commun. Ces essais ont été effectués au Malawi au cours des années 1998-1999 et 1999-2000 et ont montré que la plupart des nouveaux génotypes prometteurs de haricots étaient adaptés à la production dans le cadre des communautés agricoles. L'utilisation du chlorothalonil semblait avoir de meilleurs résultats concernant le rendement dans le cas de la lutte contre les maladies fongiques foliaires telles que les taches anguleuses du haricot, que dans le cas des maladies bactériennes foliaires comme les brûlures bactériennes communes (BBC). L'usage judicieux du chlorothalonil pourrait représenter une option importante dans les stratégies de production du haricot commun, tout particulièrement dans des régions comme celle de Bembeke où des maladies fongiques (taches anguleuses) représentent un grave problème à chaque nouvelle saison de culture. Des génotypes du haricot commun tel que LSA 191 ont montré de façon constante à Bembeke un faible taux de contamination par les brûlures bactériennes, indiquant que ce génotype peut être résistant et constituer donc un candidat approprié pour la mise en place de stratégies de lutte intégrée contre les BBC ainsi que dans le cadre de programmes de sélection. Il faudrait pouvoir fournir davantage d'efforts afin de développer de nouveaux génotypes du haricot commun susceptibles d'être incorporés dans la lutte contre les brûlures bactériennes communes, une des maladies les plus importantes du haricot commun au Malawi limitant considérablement le rendement.

INTRODUCTION

Common beans (*Phaseolus vulgaris* L.) are adversely affected by numerous biotic and abiotic stresses that result in drastic yield losses. Diseases are one of the important biotic constraints that attack common beans in Malawi (Chitedze Agricultural Research Station, 1996, 1997, 1998). The severity of a particular disease on bean plants depends on the environmental conditions during the growing season. Under conditions favourable for a particular plant disease, even insignificant diseases can attain epiphytotic proportions. The occurrence of plant diseases under natural field conditions provides an opportunity to screen the germplasm of common beans and breeding materials for resistance to the diseases (Chitedze Agricultural Research Station, 1998).

The diseases of importance in the common bean in Malawi are angular leaf spot (ALS) and common

bacterial blight (CBB). ALS is the most widespread disease in the bean-growing areas of Malawi and other parts of Africa. Different races of the pathogen are known to occur in Africa. For example, the common bean variety Napilira (CAL 143) was found to be resistant to ALS in Malawi but susceptible in Uganda, and some variation in the ALS pathogen has been observed on Napilira grown in multi-locational trials in Malawi (Anon, 1996, 1997, 1998). CBB is prevalent on common beans in all the crop-growing areas in Malawi. This disease is the most difficult to control because there are no bean varieties in Malawi known to have resistance or tolerance to CBB. Some common bean materials that have been screened in Malawi for resistance to CBB only have a partial or low level of resistance, except for the newly tested VAX lines, and even these results need to be verified (Anon., 1997, 1998). Attempts to control CBB with chemicals have failed to produce conclusive results (Anon., 1996, 1997, 1998).

It is thought that using strategies for integrated disease management (IDM) of all diseases attacking the common bean in Malawi (particularly ALS and CBB) would be a sound approach.

One of the main objectives of the Common Beans Pathology Research Programme is to aid breeders in improving germplasm. The breeders of common beans continuously develop new genotypes, which need to be screened efficiently so that materials released for cultivation in the country are suitable for production under the environmental conditions prevalent in the major bean-production areas.

The objectives of the Common Beans Pathology Research Programme in Malawi are as follows:

1. to continue the rigorous screening of promising new common-bean genotypes for resistance or tolerance to the major diseases in Malawi
2. to assess the grain yield losses caused by foliar fungal diseases in these promising new genotypes
3. to assess the grain yield losses caused by foliar bacterial diseases in these promising new genotypes
4. to develop IDM strategies for the increased production of common beans in Malawi

MATERIALS AND METHODS

The trial was run at Chitedze under a warm environment favourable for CBB on common beans. Bembeke was chosen to be a second site for this trial because of its cool environment, where ALS is a serious problem. The trial was laid out in a split-plot design where the promising new common-bean genotypes were the nine main plots.

The genotypes were Sapelekedwa and Nasaka (maintained as controls); Maluwa (CAL 113) and Sapatsika (DRK 57) (tested for the third season, which was also the final season of screening for these two newly released genotypes); Mlama 127, Rao 55, LSA 191, and EST 10 (screened for the second season, EST 10 was included as a third susceptible genotype after Sapalekedwa and Nasaka); and AFR 619 (screened for the first season in 1999/2000).

The sub-plots consisted of four rows, four metres long, replicated four times. The sub-plots comprised of two chemical treatments (chlorothalonil and copper hydroxide) and the untreated control. Chlorothalonil—a broad-spectrum fungicide—was used to control all foliar fungal diseases, while copper hydroxide was used to control foliar bacterial diseases. The untreated plots were used to determine the effects of all the foliar diseases on the grain yield of common beans at Chitedze and Bembeke.

The chemicals were applied using the manufacturer's recommended rates, with a spraying regime of seven-day intervals throughout the growing season. As a result, eight applications of the chemicals were made in the growing season in order to maximise disease control. Disease scores were recorded at the late podding stage, which was 63 days after sowing at Chitedze and 79 days after sowing at Bembeke. The disease scores were recorded on the CIAT scale of 1 to 9 points (Van Schoonhoven and Pastor-Corrales, 1987).

The bean pods were picked at physiological maturity. The fresh pods were dried further in the sun for about 10 days until they were completely dry. They were then shelled by hand and the seed was weighed to determine the yield per genotype and per chemical treatment. The seed yield per hectare was determined from the weight of the samples at 14% moisture content.

All the disease scores and seed yield data were subjected to an analysis of variance (ANOVA) using the MSTAT computer programme.

RESULTS AND DISCUSSION

The results are presented in tables 1 through 4, at the end of this paper.

Results from Chitedze

Angular leaf spot

There was a higher incidence of ALS on the common-bean genotypes at Chitedze in the 1998/99 crop growing season than in the 1999/2000 season. Significant differences were detected between genotypes, which indicated that some genotypes were resistant to ALS. Genotypes Maluwa and Mlama 127 were noted to be resistant to ALS in the 1998/99 season.

In 1999/2000, the incidence of ALS was negligible. Even on the susceptible checks (Sapelekedwa, Nasaka, and EST 10), the incidence was very low. Therefore the scores for 1999/2000 could not be used to identify resistant genotypes in this season.

Common bacterial blight

The incidence of CBB disease on common beans in the trial conducted at Chitedze in 1998/99 was very high (scores ranging from 7–9), irrespective of whether the plants were untreated or treated with chemicals. This indicated that all the genotypes were highly susceptible to CBB.

In 1999/2000, as in the previous season, CBB was the most serious disease of common beans at Chitedze, but it is encouraging that three genotypes appeared to be resistant. These were Maluwa, Sapatsika, and AFR 619. The rest of the genotypes had a lower incidence of CBB than the susceptible controls Sapelekedwa and Nasaka. The third susceptible check, EST 10, also had a lower incidence of CBB.

Grain yield

The yields of all the genotypes screened in 1998/99 at Chitedze were disastrously low, ranging from 168 kg/ha to 692 kg/ha, indicating that none of the genotypes was capable of producing high yields.

In the 1999/2000 growing season, only Maluwa and AFR 619 produced higher yields than the untreated plants. Generally, at Chitedze, chemical control of foliar fungal and bacterial diseases does not seem to be feasible for incorporation in the IDM strategies for common beans in Malawi. This is based on more than five years of trials at Chitedze, in which there has been no benefit from chemical treatments for foliar fungal and bacterial diseases on the promising new common-bean genotypes.

Results from Bembeke

Angular leaf spot

In the 1998/99 growing season, the incidence of ALS was generally high on the untreated plants (scores ranging from 3–8), except for Mlama 127, which had the lowest ALS disease incidence (score of 3), indicating resistance to the disease.

The incidence of ALS on the plants treated with chlorothalonil was low (scores ranging from 2–4), indicating that chlorothalonil effectively controlled ALS on the genotypes screened at Bembeke in 1998/99.

In the 1999/2000 growing season, the highest incidence of ALS was recorded on the untreated susceptible check EST 10 (score of 6). It is, however, atypical that the incidence of ALS on the other untreated susceptible checks Sapelekedwa and Nasaka was very low (scores of 3 and 2, respectively). The incidence of ALS on the rest of the genotypes was also low. Although significant differences were observed between both the common bean genotypes and the chemical treatments, the low incidence of ALS on the untreated susceptible checks can only indicate that ALS is unpredictable and not uniform.

Common bacterial blight

In the 1998/99 growing season, the incidence of the CBB on the untreated genotypes at Bembeke indicated a genotypic response that ranged from moderately resistant to susceptible (scores ranging from 6–8). The following genotypes produced results that indicated moderate resistance to CBB: Maluwa, Sapatsika, and LSA 191. These could be promising candidates for the development of IDM strategies for CBB in beans.

It is interesting to note that chlorothalonil, which is a broad-spectrum fungicide, tended to suppress the incidence of CBB on common beans (scores ranging from 4–8 on the chlorothalonil-treated plots versus 6–8 on untreated plants).

In the 1999/2000 growing season, the incidence of CBB was very high on the untreated susceptible genotypes (Sapelekedwa and Nasaka, with scores of 7 and 9, respectively). The rest of the genotypes showed moderate resistance to CBB (scores ranging from 4–6). It was only LSA 191 that was resistant to CBB at Bembeke in 1999/2000 (score of 3). It is very interesting that LSA 191 has been consistently observed over two growing seasons to be resistant to CBB infection. Therefore, LSA 191 should be seriously considered for use in IDM strategies for the control of CBB in Malawi and probably in the SADC region.

Grain yield

The grain yields obtained at Bembeke in 1998/99 were also disastrously low. Yields from the untreated genotypes ranged from 160 kg/ha for Sapelekedwa to 986 kg/ha for Mlama 127. For plants treated with chlorothalonil, the yields ranged from 378 kg/ha for Sapelekedwa to 1215 kg/ha for Sapatsika. However, the yields for most genotypes were better at Bembeke in the 1998/99 growing season than at Chitedze. Considerable increases in yield were obtained when chemical treatments for ALS and CBB were applied to Sapelekedwa, Maluwa, Sapatsika, Rao 55, LSA 191, and EST 10. These results indicated that control of foliar fungal diseases such as ALS led to a higher increase in grain yield (almost 50%) than the control of foliar bacterial diseases such as CBB, which led to a yield increase of almost 40% in the 1998/99 growing season at Bembeke (table 2).

The grain yields obtained at Bembeke in the 1999/2000 growing season were generally higher than those obtained in the previous season. The best yields on the untreated genotypes were produced by Sapatsika, Rao 55, and AFR 619. The other common-bean genotypes that produced good yields were Maluwa, Mlama 127, and LSA 191. Most genotypes treated with chlorothalonil produced very high yields. At Bembeke in the 1999/2000 growing season, control of ALS led to a yield increase of almost 70%. This clearly indicates that controlling foliar fungal diseases such as ALS leads to the highest grain yields being obtained. The control of CBB led to high yields from only a few genotypes, and a yield increase of only about 10%. These results are similar to those obtained in the previous season when the control of foliar fungal diseases led to a higher grain yield increase than the control of foliar bacterial diseases.

However, these results may be due to the chlorothalonil fungicide being a better and more efficient tool for eradicating foliar fungal diseases than copper hydroxide was in controlling foliar bacterial diseases.

CONCLUSIONS

1. Control of foliar fungal diseases with an effective fungicide, such as chlorothalonil, is easier to achieve and also leads to higher yield increases in common-bean genotypes than the control of foliar bacterial diseases.
2. The common-bean genotype LSA 191 consistently showed moderately resistance to CBB at Bembeke. Therefore, this genotype can be exploited in the development of IDM strategies for the production of common beans and also in breeding programmes in Malawi.
3. The judicious use of fungicides, such as chlorothalonil, to control foliar fungal diseases could be an important option in the production of common beans in areas where such diseases are serious every season, as at Bembeke.
4. The common-bean genotypes released by the breeding programme in Malawi—including Maluwa (CAL 113) and Sapatsika (DRK 57)—are good varieties for production by the farming community.
5. More research needs to be devoted to the development of more genotypes that have resistance to CBB, which is now considered to be the most important disease of common beans in Malawi.

TAKE-HOME MESSAGES

The released common-bean varieties, Maluwa (CAL 113) and Sapatsika (DRK 57), are suitable for production by the farming community in Malawi.

The control of foliar fungal diseases such as ALS with an effective fungicide like chlorothalonil is an important option in production strategies for the common bean in those areas in Malawi where these diseases are serious every season, such as at Bembeke.

The foliar bacterial diseases such as CBB are the most important diseases of common beans because they are the most challenging to manage in Malawi.

Table 1. Grain Yield Losses Caused by Fungal (ALS) and Bacterial (CBB) Diseases on Eight Common-Bean Genotypes Using Chlorothalonil and Copper Hydroxide, Chitedze, 1998/1999 Cropping Season

Genotype	Disease Scores (from 1–9) at 74 Days after Sowing							
	Angular Leaf Spot				Common Bacterial Blight			
	Untr	Chlor	CuH ₂ O ₂	Mean	Untr	Chlor	CuH ₂ O ₂	Mean
Sapelekedwa	3	1	5	3	8	7	7	7
Nasaka	3	1	4	3	8	7	8	8
Maluwa (CAL 113)	1	1	1	1	7	8	8	8
Sapatsika (DRK 57)	4	1	4	3	8	7	8	7
Mlama 127	1	1	2	1	7	7	8	7
RAO 55	5	2	6	4	7	7	8	7
LSA 191	3	1	1	2	7	7	7	7
EST 10	6	4	7	5	9	8	8	8
Trial Means	3	2	3	3	7	7	8	7
S.E. (±) Chemicals				0.62				0.12
Genotypes				0.39				0.46
C x G				0.68				0.80
C.V. (%)				50.03				21.72
Significance								
Chemicals				NS				NS
Genotypes				**				NS
C x G				NS				NS
Genotype	Grain Yield (kg/ha)				% Increase			
	Untr	Chlor	CuH ₂ O ₂	Mean	Chlor	CuH ₂ O ₂		
Sapelekedwa	213	293	168	224	38	-21		
Nasaka	428	379	321	376	-1	-25		
Maluwa (CAL 113)	421	405	338	388	-4	-20		
Sapatsika (DRK 57)	401	440	383	408	10	-4		
Mlama 127	222	295	266	261	33	20		
RAO 55	692	686	616	665	-1	-11		
LSA 191	465	378	320	388	-19	-31		
EST 10	355	467	232	352	32	-35		
Trial Means	400	418	331	383	5	-17		
S.E. (±) Chemicals				51.73				
Genotypes				60.42				
C x G				104.65				
C.V. (%)				54.69				
Significance								
Chemicals				NS				
Genotypes				**				
C x G				NS				

Note: On the CIAT disease scale, 1–3 = resistance; 4–6 = moderate resistance; 7–9 = susceptible.
Untr. = Untreated; Chlor. = Chlorothalonil; CuH₂O₂ = Copper Hydroxide.

* Significant at $p = .05$.

** Significant at $p = .01$.

NS = Not significant.

Table 3. Grain Yield Losses Caused by Fungal (ALS) and Bacterial (CBB) Diseases on Eight Common-Bean Genotypes Using Chlorothalonil and Copper Hydroxide, Chitedze, 1999/2000 Cropping Season

Genotype	Disease Scores (from 1–9) 74 Days after Sowing							
	Angular Leaf Spot				Common Bacterial Blight			
	Untr	Chlor	CuH ₂ O ₂	Mean	Untr	Chlor	CuH ₂ O ₂	Mean
Sapelekedwa	1	1	1	1	7	6	5	6
Nasaka	2	2	3	2	7	7	6	7
Maluwa (CAL 113)	2	2	1	1	3	3	2	3
Sapatsika (DRK 57)	2	1	2	1	3	3	2	3
Mlama 127	3	2	2	2	5	3	4	4
RAO 55	1	1	1	1	4	4	3	4
LSA 191	1	2	2	1	5	4	4	4
EST 10	3	3	3	3	4	4	3	4
AFR 619	1	1	1	1	3	3	3	3
Trial Means	2	2	2	2	5	4	4	4
S.E. (±) :								
Genotypes				0.31				0.45
Chemicals				0.09				0.14
Chemicals x Genotypes				0.28				0.41
C.V. (%)				35.17				20.36
Significance								
Genotypes				**				**
Chemicals				NS				**
Chemicals x Genotypes				NS				NS
Genotype	Grain Yield (kg/ha)				% Increase			
	Untr	Chlor	CuH ₂ O ₂	Mean	Chlor	CuH ₂ O ₂		
Sapelekedwa	272	204	312	6	-25	15		
Nasaka	634	599	416	7	-6	-34		
Maluwa (CAL 113)	1,667	958	877	3	-43	-47		
Sapatsika (DRK 57)	544	455	386	3	-16	-29		
Mlama 127	374	315	324	4	-16	-13		
RAO 55	716	668	508	4	-7	-29		
LSA 191	800	819	729	4	2	-9		
EST 10	191	517	164	4	171	-14		
AFR 619	1,324	1,080	1,476	3	-18	11		
Trial Means	725	624	577	4	-14	-20		
S.E. (±) :								
Genotypes				146.69				
Chemicals				52.79				
Chemicals x Genotypes				158.37				
C.V. (%)				49.34				
Significance								
Genotypes				**				
Chemicals				NS				
Chemicals x Genotypes				NS				

Note: On the CIAT disease scale, 1–3 = resistance; 4–6 = moderate resistance; 7–9 = susceptible.

Untr. = Untreated; Chlor. = Chlorothalonil; CuH₂O₂ = Copper Hydroxide.

* Significant at $p = .05$.

** Significant at $p = .01$.

NS = Not significant.

Table 4. Grain Yield Losses Caused by Fungal (ALS) and Bacterial (CBB) Diseases on Eight Common-Bean Genotypes Using Chlorothalonil and Copper Hydroxide, Bembeke, 1999/2000 Cropping Season

Genotype	Disease Scores (from 1–9) 74 Days after Sowing							
	Angular Leaf Spot				Common Bacterial Blight			
	Untr	Chlor	CuH ₂ O ₂	Mean	Untr	Chlor	CuH ₂ O ₂	Mean
Sapelekedwa	3	3	3	3	7	6	7	7
Nasaka	2	3	3	3	9	7	8	8
Maluwa (CAL 113)	2	1	2	2	4	4	5	4
Sapatsika (DRK 57)	4	2	4	4	4	3	3	3
Mlama 127	4	2	3	3	6	4	4	5
RAO 55	5	2	4	4	6	5	6	6
LSA 191	3	1	3	2	3	5	3	3
EST 10	6	4	5	5	6	5	7	6
AFR 619	4	2	4	3	5	3	5	5
Trial Means	4	2	3	3	5	5	5	5
S.E. (±) :								
Genotypes				0.50				0.38
Chemicals				0.17				0.13
Chemicals x Genotypes				0.51				0.39
C.V. (%)				33.93				15.48
Significance								
Genotypes				**				**
Chemicals				**				**
Chemicals x Genotypes				NS				**
Genotype	Grain Yield (kg/ha)				% Increase			
	Untr	Chlor	CuH ₂ O ₂	Mean	Chlor	CuH ₂ O ₂		
Sapelekedwa	247	611	326	395	147	32		
Nasaka	497	795	434	575	60	-13		
Maluwa (CAL 113)	892	1,743	1,455	1,363	95	63		
Sapatsika (DRK 57)	1,194	2,003	1,424	1,541	68	19		
Mlama 127	802	823	688	771	3	-14		
RAO 55	1,323	1,712	1,125	1,387	29	-15		
LSA 191	764	1,378	795	979	80	4		
EST 10	365	1,049	559	657	187	53		
AFR 619	1,285	2,174	1,476	1,645	69	15		
Trial Means	819	1,365	920	1,035	67	12		
S.E. (±) :								
Genotypes				174.80				
Chemicals				41.59				
Chemicals x Genotypes				124.76				
C.V. (%)				24.11				
Significance								
Genotypes				**				
Chemicals				**				
Chemicals x Genotypes				*				

Note: On the CIAT disease scale, 1–3 = resistance; 4–6 = moderate resistance; 7–9 = susceptible.
Untr. = Untreated; Chlor. = Chlorothalonil; CuH₂O₂ = Copper Hydroxide.

* Significant at $p = .05$.

** Significant at $p = .01$.

NS = Not significant.

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COLLETOTRICHUM LINDEMUTHIANUM ON BEANS IN ETHIOPIA: GEOGRAPHICAL DISTRIBUTION, IMPORTANCE, PATHOGENIC VARIATION, AND MANAGEMENT

Tesfaye Beshir

ABSTRACT

This study looked at the occurrence of bean anthracnose in Ethiopia and confirmed its importance as a limiting factor for the production of this important pulse crop. Bean anthracnose was found to increase from year to year in farmers' fields due to the monoculture of a susceptible variety (Mexican-142), with very similar effects in the Rift Valley, southern zone, and western zones of the country. There is a mean actual yield loss of 62.4% due to bean anthracnose. Host resistance was examined and, among the resistant entries, 23 were found to have wide resistance across all locations.

RÉSUMÉ

Cette étude a examiné l'incidence de l'anthracnose du haricot en Éthiopie et a confirmé son importance en tant que facteur limitatif de la production. Au cours des années, l'anthracnose du haricot a pris de plus en plus d'importance dans les champs des agriculteurs du fait de la monoculture d'une variété sensible (Mexican-142). Les mêmes effets ont été notés dans la Vallée du rift et les zones situées au sud et à l'ouest du pays. Les pertes de rendement dues à l'anthracnose du haricot atteignaient en moyenne des taux de 62,4 %. La résistance de l'hôte a été examinée et parmi les espèces résistantes, on en a découvert 23 qui présentaient une résistance élargie sur tous les sites.

INTRODUCTION

The common bean (*Phaseolus vulgaris* L) is an important food legume, providing an essential part of the daily diet in Ethiopia. It is grown as a subsistence crop under traditional farming systems, usually as an intercrop with cereals, coffee, or *enset*. Under Ethiopian conditions, beans are well adapted to altitude ranges between 1200 m and 2000 m, and to rain-fed conditions (Stewart and Dagnatchew Yirgu, 1967). Common beans are grown in most parts of Ethiopia, but production is concentrated mainly in the east (Harerghe highlands), south and southwest (Sidamo and Wolaita), the west (Keffa and Wollega), and the Rift Valley. This wide geographical range is associated with a wide range of cultivars and diseases (Bos, 1974; Habtu Assefa, 1987).

Around 1980, the area under common-bean production was about 100,000 ha (Ohlander, 1980). Estimates of the national average bean yields at that time were low, about 600 kg/ha to 800 kg/ha, which may be due to a combination of several yield constraints, among which diseases play a major role (Habtu Assefa and Dereje Gorfu, 1985). These older records gave little attention to geographic distribution and economic significance. Disease epidemiology under farmers' conditions is nearly unknown.

Of the diseases affecting bean yields, bean anthracnose (*Colletotrichum lindemuthianum* sac. and magn.) is widely distributed in the major bean-growing districts of Ethiopia. There are heavy yield losses due to anthracnose wherever susceptible bean cultivars are grown. Recently, the occurrence of the disease in Ethiopia has increased significantly (Habtu Assefa, 1987; Plant Protection Research Center, 1989). However, there is very little information on the epidemiology and management aspects of the disease. Thus, this report presents the results of a survey, loss assessment, race identification, and varietal evaluation for resistance against bean anthracnose in Ethiopia since 1992.

MATERIALS AND METHODS

Survey, laboratory, greenhouse, and field experiments for the anthracnose regional sub-project were conducted in the Plant Protection Research Center at Ambo during 1992–1995.

Survey

Survey data can help to describe the geographic distribution of the disease, its epidemiology and relative importance (Habtu Assefa, 1987; Plant Protection Research Center, 1989). The survey was conducted in major bean-production regions of the central Rift Valley (Meki, Ziway, Nazareth) where the altitude ranges between 1500 m and 1700 m above sea level, with high temperatures and erratic rainfall. The areas of Awassa, Wolaita, and Areka from Southern Ethiopia and Bako, Wollega, and Jimma from Western Ethiopia were included in this survey.

Haricot bean fields were assessed at an interval of 15 km to 20 km on farmers' and state farm fields along the main road. Sample units were selected by making a specified number of equally spaced paces; the nearest plant to the right foot was taken as the sample unit. Per sample field, 50 sample units (plants) were taken for disease assessment at growth stages close to R7 and R8 (Van Schoonhoven and Pastor-Corrales, 1987). Infected samples were also collected for laboratory analysis.

Race identification

Bean anthracnose specimens were collected from Ambo, Nazerth, Meki, Ziway, Awassa, Arsi-Negele, Areka, Jimma, Bako, and Admi-Tulu, where anthracnose is severe. In most cases, diseased pods, leaves, petioles, stems, and seeds having typical symptoms of anthracnose were collected. Isolation and single-spore cultures were prepared and inoculated on 12 standard differentials (Van Schoonhoven and Pastor-Corrales, 1987) under greenhouse conditions. The reaction of the differentials was recorded using a scale from 1–9, and race classification was based on the binary system (Barrus, 1981; Buruchara, 1991).

Greenhouse test

Five seeds of each differential were sown in 15-cm-diameter pots with three replications and kept for 10–15 days in the greenhouse at a temperature between 21 and 30. Ten-day-old seedlings were inoculated by spraying with a two-week-old culture of *Colletotrichum lindemuthianum* at the concentration of 1.2×10^6 sp/ml (Barrus, 1981) and then kept in the humid chamber for seven days. Each plant was then evaluated for its reaction against anthracnose disease.

Yield loss

Field experiments were conducted using RCBD with six replications. A susceptible cultivar (Mexican 142) was used to determine yield loss. Plot size was 4 x 3.2 m with eight rows in which four central rows were harvested. There were six treatments in the experiment. Four were spray programmes at intervals of seven days; the fifth was seed-dressing, and the control as the sixth treatment. Benomyl 20% at the rate of 2 g/litre was sprayed in accordance with the treatment type. Seed dressing was made from benomyl 20% at the rate of 0.5% kg/100 g of bean seed. Diseases were recorded for each plot every two weeks starting from the first spray, using a scale from 1–9. In addition, for intensive disease evaluation, 16 plants were randomly selected and tagged in each plot.

Data collected include leaf severity at three, five, and nine leaflets, infected pods/plant, pod severity, dead tissue, leaf area, incidence, seeds/pod, seed yield, seed weight, and the presence of other diseases.

Host-plant resistance

The International Bean Anthracnose Trial Nursery was provided by CIAT, Colombia, to facilitate the potential sources of resistance for the region. The trial was conducted from 1992–1995, comprising 100 entries every year. A susceptible cultivar, Mexican 142, was sown between and around the replications in order to increase the inoculum level. Resistant (Red Wolaita), intermediate (Black Dessie), and susceptible (Mexican 142) varieties were sown as checks after every 10 test entries. The design used was an RCBD with two replications, with plot size of 2 m x 0.60 m. Although the nurseries were exposed to natural infection, in some cases they were also inoculated with mixed anthracnose isolates. Disease reaction was evaluated before flowering, after flowering, and at podding stages on a 1–9 scale (Van Schoonhoven and Pastor-Corrales, 1987).

RESULTS AND DISCUSSION

Survey

During 1992–1995, surveys were conducted in some of the lowland areas of the Rift Valley, southern zone, and lower and mid-altitude areas (1600 m to 2150 m) of the western region. The results revealed the occurrence of different diseases throughout the major bean-growing regions of the country, the most common of which were anthracnose (*C. lindemuthianum* [Sacc. and Magn.] Bri. and Cac.), bean rust (*Uromyces appendiculatus* [Pers.] Unger and *U. phaseoli* [Pers]), common bacterial blight (*Xanthomonas campestris* pv. *phaseoli* [Erw. Smith] Dowson), angular leaf spot (*Phaeoisariopsis griseola* [Sacc.] Ferraris), and floury leaf spot (*Mycovellosiella phaseoli* [Drummond]).

The mean severity of anthracnose was 55.8%; rust, 37%; and CBB, 33.9% across all surveyed zones of the country. Furthermore, the severity of anthracnose was higher in the western zone and the Rift Valley (table 1). In farmers' fields, disease severity was generally high and the overall mean was 54.1% out of the 50 plants observed.

Table 1. Mean Severity of Anthracnose in the Major Bean-Growing Regions of Ethiopia, 1992–99

Location	Altitude (meters)	Growth Stage	Severity (%)		
			Anthracnose	Rust	CBB
I. RIFT VALLEY					
Mojo	1910	Podding	51.0	43.0	31.0
Meki	1690	Podding	69.1	44.0	31.0
Ziway	1600	Podding	61.1	45.0	30.0
Adamitul	1690	Podding	48.2	49.0	34.0
Alemaya	2020	Podding	49.3	39.0	31.0
Mean	-	-	55.7	44.0	31.4
II. SOUTHERN ZONE					
Awassa	1740	Podding	45.0	30.0	45.0
Wolita sodo	2010	Podding	93.0	45.0	35.0
Arsi Negele	1930	Podding	35.1	33.0	38.0
Mean			57.7	36.0	39.3
III. WESTERN ZONE					
Bako	1650	Podding	57.9	34.0	30.0
Didesa	1600	Podding	45.9	31.0	30.0
Metu	1610	Podding	35.1	29.0	25.0
Jimma	2000	Podding	72.3	35.0	33.0
Ambo	2150	Podding	59.3	30.0	38.0
Mean			54.1	31.8	31.2

In all four years, a total of 108 isolates were collected, some of which were from experimental fields where many bean genotypes were grown, predominantly Mexican 142, which has recently shown a higher incidence of anthracnose. This might be due to susceptibility of Mexican 142, which is widely grown in Ethiopia, to the relative increase of a race that affects it, an increase of inoculum levels in the field due to infected debris, or sowing of infected seeds (which contributes to the build-up of anthracnose inoculum in the region). Thus the prevalence and severity of the disease have steadily increased in farmers' fields and experimental sites.

Race identification

In 1992, race studies were initiated and isolates characterised from different bean-growing regions in the country: Bako, Ambo, Ziway, Awassa, Areka, Adami Tulu, Meki Jimma, and Alem Tena. Fifteen races of *C. lindemuthianum* were identified (table 2). Among the 15 races, race 128 and 511 occurred most frequently in every location and were designated as the dominant occurring races. Races like 1, 1023, 898, 525, 1009, 499, 718, 952, 585, 961, 1011, 712, and 296 were unique to a single location (table 3).

Table 2. Race Study on Bean Anthracnose Collected from Different Locations

Differentials	Ambo	Awassa	Meki	Bako	Areka	Ziway	Jima	
Michelite	1	1	1	1	R	1	R	1
MDRK	2	R	R	2	2	2	R	R
Perry Marrow	4	R	R	4	R	R	R	4
Cornell 48242	8	8	R	8	8	R	R	8
WIDUSA	16	R	R	16	R	16	R	R
Kaboon	32	R	R	32	R	32	R	R
Mexico 222	64	64	64	64	R	64	R	R
PI 207262	128	R	128	128	128	128	128	R
TO	256	R	256	256	256	256	R	256
TU	512	512	512	R	512	512	R	R
AB 136	1024	R	R	R	R	R	R	R
G 2333	2048	R	R	R	R	R	R	R
<i>Race Denomination</i>	585	961	511	906	1011	128	269	

Note: R = Resistant. Numbers indicate susceptibility.

Table 3. Races of *Colletotrichum lindemuthianum* Identified, Different Locations, 1992–95

Year	Types of races								
	Ambo	Awassa	Bako	Ziway	Areka	A. Tulu	Meki	A. Tena	Jimma
1992	525 1	1009	898 1023	128 511	499	718	511 128	952	—
1993	585	1009 961	906	128 511	1011	712	511 128	952	269
1994	525 585	1009 961	898 906	128 511	499 1011	718 712	511 128	952	269
1995	525 585 1	1009 961	898 906 1023	128 511	499 1011	718 712	511 128	952	2697

The racial pattern of *C. lindemuthianum* for the 1995/96 crop season did not show any shift in races; however, insignificant variations in distribution was observed, compared to the preceding year.

Yield loss

The yield-loss study was conducted on bean anthracnose over four years on experiment stations and on-farm trials. The severity of the disease on the control plot was high at different stages, compared to the protected crops.

In 1992, due to low anthracnose levels, there was no difference in yields from fungicide treatments, but the other years, the level of disease was high enough for the effect of the disease on yield to be measured. The mean actual yield loss was found to be 62.4%, and the mean actual seed weight loss was 43.8%. (table 4), (Zadoks and Schein, 1979).

The anthracnose developed very quickly in the on-farm trials, with an average severity of 76.6%. The mean loss in yield was 67.2% (table 5).

Host-plant resistance

New sources of resistance for bean anthracnose were identified from among the accessions from different geographic regions with desirable agronomic traits, such as growth habit, grain colour, and size: 59% of the

Table 4. Effect of Bean Anthracnose on Yield and Yield Components of Haricot Bean, Ambo, 1992–1995

Treatment	Severity (%)	Pods/Plant	Seeds/pod	Seed weight		Yield	
				Grams	Actual loss (%)	ton/ha	Actual loss (%)
7 days	11.8 D	18.9 A	5.8 A	15.8 A	49.4	2.025 A	62.8
14 days	17.9 C	13.3 C	4.5 C	11.1 C	27.9	1.385 C	45.7
21 days	25.1 B	13.3 C	4.3 CD	10.4 D	23.1	1.252 D	39.8
28 days	27.4 B	13.6 C	4.2 D	9.8 E	18.4	1.188 D	36.7
Seed treat.	16.1 C	14.9 B	5.1 B	13.5 B	40.7	1.646 B	54.3
Control	83.5 A	8.7 D	3.5 E	8.0 F	—	0.756 E	—
Lsd 0.01	2.633	0.735	0.21	0.57		0.07	—
CV	9.03	5.64	4.98	5.31		5.14	—

Table 5. Yield Loss in Haricot Beans from Bean Anthracnose, on-Farm Trial, Meki, 1994–95

Crop Season	Treatment	Anthracnose Severity (%)					Yield		Seed wt.	
		V ₄	R ₅	R ₆	R ₇	R ₈	Grams/plot	Actual loss (%)	Grams	Actual loss (%)
1994	P	9.3	13.4	16.1	19.7	19.3	1508.9		157.1	
1995	NP	15.3	35.3	45.9	55.5	67.8	522.2	65.4	111.8	28.8
	P	10.2	17.2	19.5	21.1	15.1	1680.5		146.9	
	NP	25.0	35.0	47.9	65.1	85.4	522.5	68.9	94.4	35.7
MEAN	P	9.8	15.3	17.8	20.4	17.2	1594.7		152.0	
	NP	20.2	35.2	46.9	60.3	76.6	522.4	67.2	103.1	32.2

Note: P = Protected; NP = Not Protected.

V₄ = 3rd trifoliolate leaves; R₅ = Pre-flowering; R₆ = Flowering; R₇ = Pod formation; R₈ = Pod filling.

entries were resistant at Meki, 71% at Ambo, 80% at Awassa, and 57% at Areka. Fewer entries were classified as intermediate.

Weather conditions during the evaluation periods were favourable for the development of both the crop and the pathogen (except at Awassa). Entries like AB 136, G 2333, Ecuador-299, BAT-448, contanex, Negrow-150, Eth-39, Perry Marrow, ACV-17, Princor, CEN 60970, PVAD 1184, PVAD 791, PAD 37, A 4754, A 613, G 18549, G 19175, G 02618, G 05653, G 11680, VRB 81069, G 07199 were resistant across all locations. About 50 landraces have been collected to be tested against anthracnose on the basis of Meso-American and Andean pathogen gene pools.

CONCLUSIONS

Bean anthracnose, rust, CBB, ascochyta blight and angular leaf spot were the major diseases of the common-bean crop in the surveyed areas of the country.

The race analysis of bean anthracnose revealed 15 races to exist in Ethiopia, based on the differential variety test. Among these, race 128 and 511 were consistently found in all the test locations.

There was a yield loss of 62.8% due to anthracnose, justifying its economic importance in Ethiopia.

Nine varieties showed a high degree of resistance against bean anthracnose in all locations. These materials can be of great help in the bean-breeding programme of the East African and Great Lakes Region where similar races of the pathogen exist.

Recommendations

The materials that were resistant at all the tested sites were recommended to the national program. Some of these materials are already in the breeding program at Nazareth Research Center, Ethiopia.

FUTURE PLANS

1. monitoring races of bean anthracnose in Eastern Africa with collaborating countries (Kenya, Uganda, Madagascar, and Tanzania)
2. studying the virulence and aggressiveness of the bean anthracnose races obtained in the region
3. developing a race map for African bean anthracnose in Eastern Africa
4. continuing germplasm evaluation, including non I-gene PADN and IBCMBRN or breeding lines developed in specific programs

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DEVELOPMENT OF AN INTEGRATED PEST AND RESOURCE MANAGEMENT PACKAGE FOR THE CONTROL OF BEAN STEM MAGGOT (*Ophiomyia* spp.) IN MALAWI

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ABSTRACT

Fifteen IPM packages with a combination of five different options for the control of bean stem maggot (BSM) (*Ophiomyia* spp.) were tested at Chitedze, Ntchenachena, and Bembeke Agricultural Research Stations. These included fertiliser, seed dressing, earthing-up, foliar insecticide, and the use of resistant varieties. The performance of each package was evaluated based on several factors, such as plant mortality due to BSM, number of BSM on dead plants, damage scores, parasitoid populations, and seed yield. The results indicated that the use of both chemical and cultural practices, together with host-plant resistance, was superior over strategies that had one or more options missing. The advantage of chemical spraying over seed dressing is also discussed. Since the use of chemicals may not be feasible, they could be substituted with botanical pesticides, such as neem, *Tephrosia* spp., and other locally available botanicals. There is a need to explore the availability of such indigenous knowledge from bean growers in the major bean-growing areas of Malawi.

RÉSUMÉ

Quinze ensembles de techniques agricoles de lutte intégrée contre les ravageurs associés à cinq différentes options de lutte contre la mouche du haricot (*Ophiomyia* spp.) ont été expérimentés aux stations de recherche agricoles de Chitedze, Ntchenachena et Bembeke. Ces ensembles comprenaient des fertilisants, la désinfection des semences, la pratique du buttage, des insecticides foliaires et l'utilisation de variétés résistantes. Les résultats de chaque ensemble ont été évalués sur la base de différents facteurs, tels que la mortalité par rapport au nombre de mouches, les taux de dommages, les populations parasitoïdes et le rendement des semences. Les résultats ont indiqué que l'utilisation de substances chimiques et de pratiques culturelles associées à la résistance de la plante-hôte étaient préférables aux stratégies qui excluaient l'une ou plusieurs de ces options. L'avantage de la pulvérisation de substances chimiques par rapport à la désinfection des semences est également montré. Lorsque des substances chimiques ne peuvent pas être utilisées, elles peuvent être remplacées par des pesticides botaniques tels que le margousier, *Tephrosia* spp., et d'autres produits végétaux disponibles localement. Il est nécessaire d'étudier les connaissances indigènes des cultivateurs de haricots disponibles dans les principales régions de cultures du haricot du Malawi.

INTRODUCTION AND LITERATURE REVIEW

The common bean, *Phaseolus vulgaris*, is a good source of protein for the majority of people in both urban and rural communities in Malawi. Beans are also a source of cash and foreign-exchange earnings. However, bean productivity in Malawi, like that of most grain legumes is constrained by insect pests, among other factors (Anon., 1995). On-farm surveys have indicated insect pests like the bean fly (*Ophiomyia* spp.), leaf beetle (*Oothea* spp.), and aphids (*Aphis fabae*), to be the main pests of beans in the country. While bean flies and leaf beetles are important during the main cropping season, aphids tend to be more serious on winter crops or in times of severe drought.

The survey reported here confirmed earlier findings that showed bean flies to be the main insect pest on beans in the country, (Kapeya et al., 1993; Letourneau, 1994). In Africa, bean flies have been reported to caused the total yield to be lost in some seasons (Karel, 1989). In Malawi, yield losses of up to 49% have been reported in the southern region, justifying the search for appropriate control measures (Kapeya et al., 1993). Various control methods for bean flies include applications of endosulfan, dimethoate, and imidacloprid as seed dressings or foliar sprays (Trutmann et al., 1992; Abate, 1991; Ross, 1997); cultural

practices, such as earthing-up, increased plant density, time of planting, oil amendments, and soil moisture preservation through mulching (Ampofo, 1993; Letourneau, 1994; Ross, 1997). However, the efficiency of these practices depends on the time of application and environmental conditions, and in some communities, some of the methods may be incompatible with traditional practices (Ampofo, 1993). There are also sources of resistance that can be used to develop host-plant resistance as a control mechanism (Ross, 1997).

Since the efficiency of the cultural methods depends on time of application and environmental conditions, it is unlikely that a single practice can be recommended for consistent, long-term control of the bean fly. The use of an integrated approach would therefore be appropriate, since this would offset the failure of any single method. In addition, while not condoning the use of chemicals, we note that further control can be achieved if insecticide use is incorporated with cultural control methods. It is important to improve the method of applying insecticides in order to decrease contamination of the broader agro-ecosystem to improve the survival of natural enemies. Seed treatments with systemic pesticides are one possible chemical option since they use minimal dosages and high ecological selectivity compared to sprays (Metcalf, 1980).

Furthermore, IPM approaches that are presented as packages should take farmers' socio-economic and environmental circumstances into consideration, bearing in mind the fact that most Malawian farmers rely on their own or family labour for both farming and earning off-farm income, which is, in most cases, in short supply. Similarly, these packages should be developed with the low income-earning capacity of smallholder farmers in mind. Finally, they should ensure reduced disruption of the ecosystem through proper selection of chemical insecticides.

It is therefore the general objective of this proposed work to develop an IPM package for use in different agro-ecological zones for the control of the bean fly (*Ophiomyia* spp.) in Malawi. Specifically, the research will examine the impact of different IPM packages on the biological environment.

MATERIALS AND METHODS

The trial was carried out in three areas—Bembeke, Chitedze, and Ntchenachena—in a randomised complete block replicated three times. Gross plot was five rows, 4 m long and 50 cm apart with a net plot of 3 central rows of 3 m each. Beans were planted 15 cm apart on ridges. Infested rows of Nasaka were planted between treatment plots and replicates three weeks before bean planting. Treatments included 15 combinations of control strategies, such as fertiliser application (F), seed dressing (SD), earthing up (E), foliar insecticide spray (Fs), and use of resistant (R) or susceptible (S) varieties.

Two varieties, susceptible Nasaka and resistant EXI 52 were used. Dimethoate (20 EC) was used to control bean fly adults from one week after emergence to three weeks later. Earthing-up was done from two weeks after emergence when weeding was required. Imidacloprid was used for seed dressing at 5g/kg of seed, and fertiliser was applied at 300 kg/ha using 23:21:0+4S.

Data were collected on the plant stand at one week after emergence, total plant mortality and total bean flies emerging from the dead plants, number of parasitoids emerging from collected pupae, damage score of sampled plants, and pod and seed yield.

RESULTS AND DISCUSSION

Mortality due to bean stem maggots

Mortality was significantly different ($p > .001$) at all sites but was higher at Chitedze than Ntchenachena and Bembeke. In general treatments 13, 14, and 15 (which lacked both insecticide treatments and fertiliser applications) had the highest mortality from bean stem maggots (BSM) (table 1).

Number of bean stem maggots from dead plants

There were also higher BSM populations at Chitedze than at Ntchenachena, with significant differences ($p > .05$) at both locations. Again, treatments 13, 14 and 15 had the greatest infestation.

Damage score

Significant differences ($p > .001$) in damage scores were found at Ntchenachena but not at Chitedze, where the mean damage score was high (see table 1).

Table 1. Effect of IPM Packages on Bean Fly Infestation and Yield of Phaseolus Beans

Treatment	Mortality due to BSM	Total BSM	Number of Parasitoids	Damage score	Pod yield	Seed yield (kg/ha)
Chitedze, 2000						
Sd, F,E, R	1	0	0	1.0	783	375
Sd, F,E, S	1	3	0	1.0	770	355
Sd, F, R	2	0	0	1.0	387	217
Sd, F, S	2	4	0	1.0	606	285
Sd, E, R	4	8	7	2.0	470	160
Sd, E, S	2	5	3	1.0	265	135
Fs, F,E, R	1	4	0	1.0	1105	630
Fs, F,E S	1	5	0	2.0	1069	580
F,E R	1	4	2	1.0	386	165
F,E, S	3	8	0	3.0	447	160
F, R	1	2	11	1.0	440	250
F, S	2	6	0	3.2	404	180
E, R	9	16	0	4.5	116	100
E, S	17	36	4	5.0	100	30
No control	17	40	1	5.0	0	0
Mean	4.2	9.4	2	2.2	489.9	241.5
SE	0.3	0.8			185	91.3
Significance	***	***			***	***
Ntchenachena, 2000						
Sd,F,E, R	0	0	2	1.0	891	508
Sd, F,E., S	0	0	2	1.0	325	192
Sd, F, R	0	0	0	1.0	1016	533
Sd, F, S	0	0	0	1.0	258	150
Sd, E, R	1	0	3	2.0	240	317
Sd, E, S	0	0	2	1.0	267	176
Fs, F,E, R	0	4	2	3.0	147	583
Fs, F,E S	5	7	2	3.4	141	425
F,E R	0	0	1	1.0	200	175
F,E, S	12	14	16	3.6	1225	620
F, R	0	0	0	1.0	100	59
F, S	5	14	1	3.0	866	420
E, R	3	1	0	1.0	500	290
E, S	7	23	5	3.7	330	60
No control	9	27	7	4.5	250	60
Mean	2.8	6.0	3	2.1	322.9	304.5
SE	0.3	0.8			122	115
Significance	***	***			***	***

Table 1. (continued)

Treatment	Mortality due to BSM	Total BSM	Number of Parasitoids	Damage score	Pod yield	Seed yield (kg/ha)
Bembeke, 2000						
Sd, F,E, R	0	1	0	1.0	850	427
Sd, F,E, S	0	0	0	1.0	1165	566
Sd, F, R	0	0	0	1.0	716	627
Sd, F, S	0	0	0	1.0	564	376
Sd, E, R	2	6	1	3.4	459	306
Sd, E, S	0	0	1	1.0	929	666
Fs, F,E, R	2	4	1	3.0	810	540
Fs, F,E S	2	6	2	3.4	785	523
F, E, R	3	7	2	4.0	315	240
F, E, S	11	12	6	4.9	322	215
F, R	0	2	0	1.3	465	310
F, S	1	6	0	3.5	195.2	122
E, R	0	1	0	1.0	106.5	78.
E, S	17	23	10	4.4	73.8	40.6
No control	23	27	11	5.0	0.0	0.0
Mean	4.06	6.33	2	2.6	517.0	336.0
SE					195	127
Significance	***	***			***	***

*** $p = .001$.

Parasitoid population

Differences in parasitoid populations were significant ($p > .05$) among the different control strategies; however, insecticide control did not seem to reduce the population of parasitoids at Chitedze, where some control packages incorporating chemical control had high populations. This is in contrast to Ntchenachena, where only those strategies that did not include chemical control had high parasitoid populations.

Yields

Yield differences were significant ($p > .001$) at both sites, where high yields were observed when foliar spraying was combined with fertilisers, earthing-up, and the use of a resistant variety.

The results confirms the superiority of using both chemical and cultural practices together with host plant resistance over those control strategies that have one or more of these strategies lacking. In addition chemical control by spraying has shown to be more superior to seed dressing. While these results indicate the importance of integrating all four control strategies in controlling BSM, it is however not known whether this is economical or not. It is therefore imperative that an economic analysis be done to assess whether farmers are better off adopting a package that includes all control strategies.

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CONTRÔLE DE AGROTIS IPSILON, UN DES RAVAGEURS DU HARICOT À MADAGASCAR

Richard Randriamanantsoa

RÉSUMÉ

Pratiquée dans différentes régions de Madagascar, aussi bien en saison (dans les collines) qu'en contre-saison (sur rizière), la culture du haricot commun, Phaseolus vulgaris, constitue une importante source de revenu pour les paysans malgaches. Cependant elle est sujette à des attaques par des ravageurs dont les principaux sont Apoderus humeralis et Agrotis ipsilon. Une étude réalisée avec la participation d'une communauté paysanne a évalué des méthodes visant à protéger les cultures de haricot par la maîtrise du ravageur Agrotis ipsilon. Elle a permis de constater que le traitement des semences soit par l'application du fongicide/insecticide APRON+ 50 D, soit par l'épandage d'appâts empoisonnés composés de son de riz, sucre, diazinon et d'eau permet de réduire les dégâts occasionnés par ce ravageur. En outre, l'étude a révélé que la poudre de graines de Melia azedarach utilisée comme protection naturelle, inhibe la germination des graines de haricot tandis que la pratique paysanne qui consiste à épandre de la cendre avant le semis est efficace.

ABSTRACT

In Madagascar bean crops are one of the farmers' main sources of income. The common bean, Phaseolus vulgaris, is cultivated throughout the island's different regions and during various seasons (the rainy season on the hills and off-season cultivation on irrigated rice fields). However, the crops are threatened by insect pests, mainly Apoderus humeralis and Agrotis ipsilon, which attack the plants during the vegetative stage. A study was undertaken, with farmer-community participation, to assess the effects of various pest-control methods on Agrotis ipsilon. Findings showed that both the chemical seed treatment APRON+ 50DS (10% Metalaxyl + 34% Fioradicarb + 6% Carboxin) and the use poisoned baits made up of rice bran, sugar, Diazinon, and water were effective in reducing the damage caused by Agrotis ipsilon. Test results also revealed that the use of Melia azedarach powder, as a botanical pesticide, had an adverse effect on bean sprouting, while the local practice of spreading ash along planting rows before sowing is effective.

INTRODUCTION

Madagascar est la plus grande île de l'océan Indien, avec une superficie de 592 000 km². Le riz est la principale culture et constitue l'aliment de base des Malgaches. Les cultures industrielles (canne à sucre, vanille, girofle, etc.) et les cultures maraîchères et vivrières (maïs, soja, manioc et haricot) constituent les principales sources de revenu des paysans.

Le haricot est cultivé partout dans l'île, aussi bien dans la zone côtière que sur les Hauts-Plateaux—culture de bas-fond et culture sur « tanety » (colline). Selon les régions, et en fonction de la pluviométrie et de la disponibilité des terrains, la culture se pratique une, deux ou trois fois par an : culture de saison, de demi-saison et de contre-saison (sur les rizières). Dans les régions des Hauts-Plateaux, le haricot est cultivé deux fois par an, par suite de l'exiguïté des parcelles, qui sont également destinées à d'autres cultures. Comme toutes les cultures, le haricot est sujet à de nombreuses attaques de ravageurs, dès le stade levée et jusqu'au stockage. *Apoderus humeralis*, *Ophiyomia* sp. et *Agrotis ipsilon* figurent parmi les principaux ravageurs menaçant le haricot durant son cycle végétatif. Le travail présenté ici s'insère dans la recherche de solutions pour aider les paysans à résoudre leurs problèmes, et plus particulièrement à s'armer contre les attaques d'*Agrotis ipsilon*, ravageur très connu des paysans qui menace leurs cultures de haricot, de tomates et de maïs.

MATÉRIELS ET MÉTHODES

Conduite

Ce travail a été conduit avec une communauté paysanne de la commune d'Ambohimiarivo, dans la sous-préfecture d'Antsirabe II. Situé à 35 km d'Antsirabe, ce site est l'une des principales zones productrices de la région, zone de cultures fruitières (raisin, pêche, pommes), maraîchères (principalement de la tomate) et vivrières, notamment le haricot. La variété de haricot *Soafianarana* est la plus courante mais depuis notre intervention dans la communauté beaucoup de paysans ont adopté les nouvelles variétés *Goiano précoce*, *Ikinimba*, *G13671* et *Xan 76*.

L'approche participative a été la démarche adoptée pour mieux impliquer les paysans.

Mise en place

Une discussion préliminaire avec les paysans a permis de connaître leurs pratiques de protection des cultures contre les attaques d'*Agrotis ipsilon*, de manière à pouvoir en tenir compte dans les différents traitements utilisés. Trois localités ont été considérées pour la conduite du travail.

Pour l'étude, la variété *Soafianarana* a été utilisée. Le semis a été réalisé en ligne, avec un écartement de 10 x 50 cm, à raison de 1 graine par poquet. Avant le semis, chaque parcelle élémentaire mesurant 12 m² (3 x 4 m) a été fertilisée d'une dose de 10 tonnes de fumier de ferme par hectare, en apportant 200 kg de NPK et 300 kg/ha de dolomie par hectare. Les paysans ont exécuté tous les travaux de préparation du sol et d'entretien (sarclage). La mise en place du dispositif a été précédée d'une séance de formation sur les différents stades du haricot, sur la biologie du ravageur, sur les différents traitements proposés et les conditions d'expérimentation requises.

Dispositif expérimental

Nous avons utilisé un dispositif en blocs à quatre répétitions et appliqué les six traitements suivants :

T₀ = témoin non traité

T₁ = pratique paysanne (utilisation de la cendre à raison d'un kilogramme par parcelle élémentaire)

T₂ = traitement des semences par un produit chimique, le fongicide/insecticide Apron plus 50 DS (méta-laxyl 10 % + carboxine 6 % + furathiocarbe 34 %). Doses de 250 g/100 kg de semences.

T₃ = traitement du sol par un produit chimique (basudine 10 G ; matière active diazinon). Doses de 15 kg/ha.

T₄ = utilisation d'appâts empoisonnés (son de riz + basudine 10 G + sucre + eau). Doses de 30 kg/ha.

T₅ = traitement de semences à l'aide de la poudre de graines de *Melia azedarach* (Miliacea), utilisée à la dose de 500 g/10 kg de semences

Préparation des produits et application :

- La cendre provient généralement de l'incinération de débris végétaux (mauvaises herbes feuilles et branches d'arbres que les paysans ramassent un peu partout) ; elle est appliquée le long de la ligne de plantation avant le semis.
- La poudre des graines de *Melia azedarach* est obtenue en pilant des fruits mûrs de *M. azedarach* pour séparer la pulpe de la graine ; la graine est séchée, puis broyée et réduite en poudre ; la poudre est mélangée aux semences au moment du semis.
- L'appât empoisonné est composé de son de riz mélangé au produit chimique, avec ajout de sucre et d'eau ; l'épandage s'effectue en surface le long de la ligne de plantation, le soir après le semis.

Observations et récolte

Dix jours après le semis, on dénombre les plants levés dans chaque parcelle élémentaire. Ensuite, aux stades V2, V3 et V4 de la culture, on compte les plants attaqués en notant bien par rapport à quel traitement.

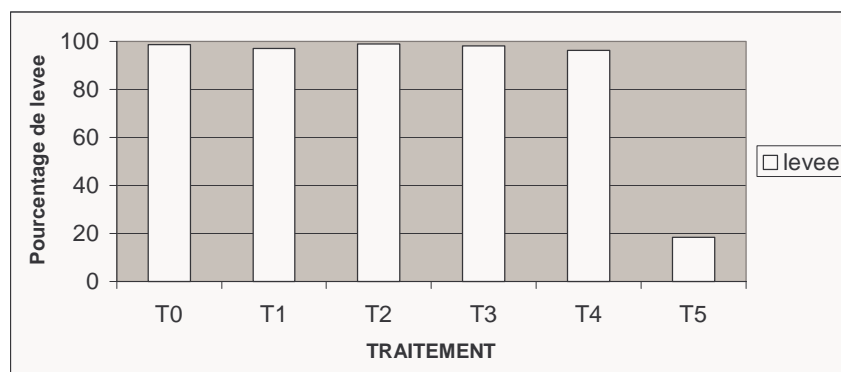
Chaque parcelle élémentaire fait l'objet d'une récolte séparée ; les produits recueillis sont pesés séparément.

RÉSULTATS ET DISCUSSION

Levée des plants :

La levée des plants a été satisfaisante dans toutes les parcelles, sauf dans celle où les semences ont été traitées avec la poudre de *Melia azedarach*. Le pourcentage de levée variait de 98,47 à 18,47 : le meilleur résultat fut obtenu avec le traitement T₂, à l'Apron +50 DS (figure 1). Le pourcentage le plus faible correspondait donc au traitement des graines avec de la poudre de *Melia azedarach* (T₅).

L'application de la poudre des graines de cette plante a affecté la germination des graines de haricot. En effet les graines traitées sont devenues molles et ratatinées, ce qui a entraîné la faible levée dans ces parcelles. Un test de germination effectué au laboratoire sur des semences enrobées de poudre de *Melia azedarach* a confirmé ce résultat.



T₀ = Témoin, T₁ = Pratique paysanne, T₂ = Traitement de semences par APRON +50DS, T₃ = Traitement de sol par Basudine 10G, T₄ = Utilisation d'appâts empoisonnés, T₅ = Traitement de semences par la poudre de *Melia azedarach*.

Figure 1. Pourcentage moyen de levée selon les différents traitements

Attaque selon les stades de la culture

La figure 2 fournit une représentation graphique de l'impact des différents traitements aux différents stades de la culture du haricot.

Stade V2

La faible levée observée avec le traitement des semences en les mélangeant à de la poudre de *Melia azedarach* a empêché l'évaluation des attaques de ravageur et l'analyse du rendement dans les parcelles concernées.

Dans les autres parcelles, malgré un taux d'attaque faible, variant de 3,89 % à 6,81 %, l'on a pu observer que les attaques subies au stade V2 de la culture étaient plus importantes qu'aux autres stades. Ceci montre que les dégâts d'*Agrotis ipsilon* sont plus à craindre pendant les premiers stades lorsque les plants sont jeunes.

On note que le traitement des semences avec APRON+ 50 DS (le mélange d'insecticide et de fongicide) donne le résultat le plus intéressant.

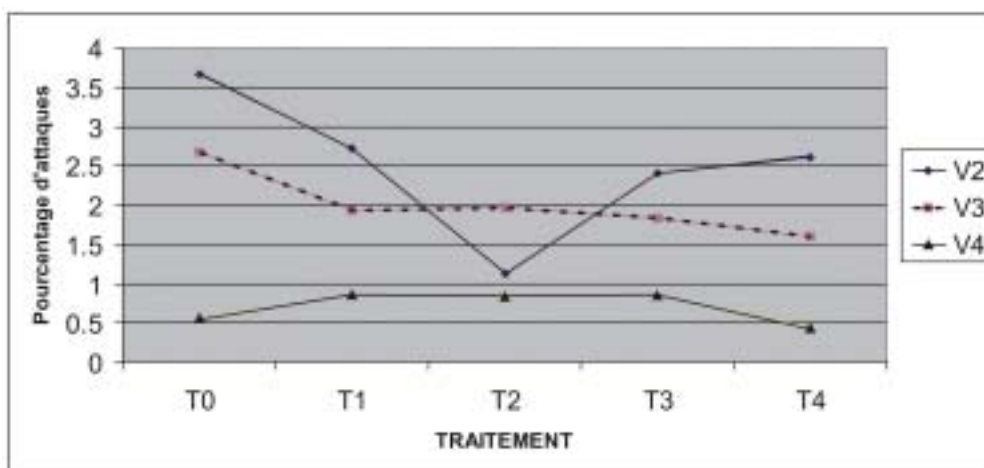
Stade V3

Au stade V3, on constate un taux d'attaque faible pour tous les traitements, par rapport au témoin non protégé, y compris dans le traitement T₁ par la cendre. En effet l'utilisation de la cendre a protégé la culture contre les attaques des vers gris (*Agrotis ipsilon*), en ayant les mêmes effets que les autres traitements. Toutefois, une étude sur la nature des combustibles utilisés mérite d'être abordée.

Stade V4

Au stade V4 de la culture, le taux d'attaque ne dépasse pas 0,80 %. En effet, à ce stade les tiges se sont lignifiées et le ravageur ne réussit plus vraiment à les inciser. Les dégâts se limitent à la présence d'une incision au niveau de la tige. Il arrive que l'incision perce toute l'écorce et que la plante se fane et meurt mais une attaque d'*Agrotis ipsilon* n'est plus vraiment à craindre à ce stade.

La figure 2 montre à la fois qu'en général le taux d'attaque demeure relativement faible et que les attaques sont les plus nocives lorsque la culture est encore très jeune : la menace s'affaiblit dans les stades avancés de la croissance végétative. L'évolution des attaques sous l'influence des différents traitements indique l'intérêt



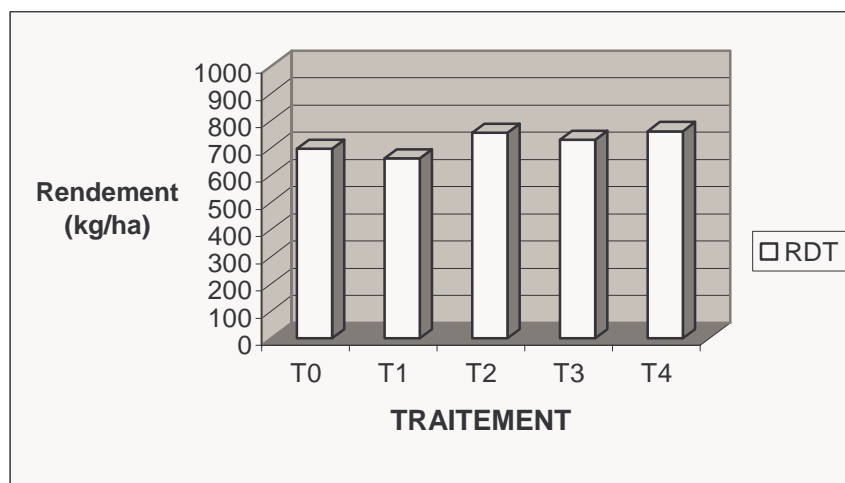
T₀ = Témoin, T₁ = Pratique paysanne, T₂ = Traitement de semences par APRON+50DS, T₃ = Traitement du sol par Basudine, T₄ = Utilisation d'appâts empoisonnés.

Figure 2. Pourcentages moyens d'attaque d'*Agrotis ipsilon* aux différents stades de la culture et en réponse aux différents traitements

de protéger le haricot contre les attaques d'*Agrotis ipsilon*. La protection chimique qui consiste à traiter les semences en appliquant un insecticide approprié (en l'occurrence, un mélange d'insecticide fongicide) est la plus intéressante.

Analyse du rendement

Malgré les divers traitements et malgré l'apport d'une bonne fertilisation, le rendement moyen du haricot n'a pas dépassé une tonne par hectare. Ceci n'est pas lié à l'attaque du ravageur mais plutôt à la variété elle-même. Cependant, une bonne protection permet d'améliorer le rendement (fig. 3) par rapport au témoin non protégé.



T₀ = Témoin, T₁ = Pratique paysanne, T₂ = Traitement de semences par APRON+50DS, T₃ = Traitement de sol par Basudine, T₄ = Utilisation d'appât empoisonné.

Figure 3. Rendement moyen (en kg/ha) selon les différents traitements

CONCLUSION

Les résultats des tests effectués dans le cadre de cette recherche ont permis de tirer les conclusions suivantes. On note d'abord que, contrairement à l'expérience acquise dans les cas du riz pluvial et du maïs, l'utilisation de la poudre des graines de *Melia azedarach* pour protéger les semences de haricot a une influence négative sur la germination des graines de haricot. Par contre, le traitement des semences en utilisant un produit chimique s'avère intéressant. Enfin, l'étude a confirmé l'importance de la pratique paysanne de mélanger de la cendre aux semences afin de protéger la culture de haricot contre les attaques des vers gris, *Agrotis ipsilon*.

Cette pratique paysanne est efficace : la cendre que beaucoup de paysans utilisent pour fertiliser leur culture par manque de fumier de parc réduit effectivement les dégâts causés par les attaques des ravageurs. Les paysans disposent de beaucoup de pratiques qui méritent d'être valorisées car elles sont simples et la plupart du temps disponibles sur place.

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FIELD MANAGEMENT OF *ACANTHOSCELIDES OBTECTUS* USING BOTANICALS, SYNTHETIC INSECTICIDES, AND ENTOMOPATHOGENS

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ABSTRACT

The common bean weevil, Acanthoscelides obtectus (Say), is a primary pest that infests beans while still in the field and continues during storage. There is, however, a lack of information on the most susceptible stage of pod development, the relationship between bruchid damage and other pod pests, bruchid carry-over from the field into storage, and pest-management protocols. Studies were therefore conducted to establish the susceptibility of pods at different stages of development and the effect of chemical insecticides, bio-pesticides, and cropping systems on A. obtectus infestations. The onset of bruchid field infestations was determined with sticky-baited, sticky-non-baited, and water traps. The effect of insecticides and bio-pesticides on field infestations was determined by spraying beans under pre-determined regimens with different formulations of cow urine, Phytolacca dodecandra, Tagetes minuta, Capsicum frutescens, Nicotiana tobacum, suspensions of Beauveria bassiana spores, Ambush 5% EC, and Fenitrothion 50% EC. The influence of mixed inter-cropping, row inter-cropping, and sole cropping on field infestations was also investigated. A. obtectus was detected in the field as early as the pod-formation stage and its population increased significantly as the pods matured. The most susceptible pod stages were established as physiological and harvest maturity. Ambush, crude concoctions of tobacco, Phytolacca in water and soap, and B. bassiana fungal spores in water were quite effective in reducing A. obtectus infestations in the field. Beans harvested from the mixed inter-crop with maize were the least damaged.

RÉSUMÉ

La bruche du haricot commun, Acanthoscelides obtectus, est le principal ravageur qui s'attaque au haricot dans les champs et qui poursuit son action dans les lieux d'entreposage. Il existe toutefois un manque d'information sur la phase la plus sensible du développement de la gousse, sur la relation entre les dommages causés par les bruches et les autres ravageurs des gousses, sur le passage des bruches des champs aux lieux d'entreposage ainsi que sur les protocoles de lutte contre les ravageurs. Des études ont donc été réalisées afin de déterminer la sensibilité des gousses dans les différentes phases de développement et les effets des insecticides chimiques, des biopesticides et des systèmes de cultures sur les attaques de A. obtectus. Le commencement de l'attaque des champs par les bruches a été déterminé à l'aide de pièges englués munis d'appâts, de pièges englués sans appât et de pièges à eau. Les effets des insecticides et des biopesticides sur l'attaque des champs par les bruches ont été déterminés au moyen de pulvérisations des haricots selon des schémas prédéterminés comportant différentes formulations d'urine de vache, Phytolacca dodecandra, Tagetes minuta, Capsicum frutescens, Nicotina tobacum, de suspensions de spores de Beauveria bassiana, de perméthrine 5 % EC et de fenitrothion 50 % EC. L'impact des cultures associées, des cultures intercalaires et de la monoculture sur les attaques subies par les champs a également été étudié. A. obtectus a été détecté dans les champs dès la phase de formation de la gousse et sa population augmentait de manière significative à mesure que les gousses mûrissaient. La maturité physiologique et la maturité de récolte représentaient, pour les gousses, les phases les plus vulnérables. La perméthrine, des préparations crues à base de tabac, Phytolacca dans de l'eau savonneuse et des suspensions de spores fongiques de B. bassiana permettaient de réduire de manière efficace les attaques de A. obtectus en champ. Les haricots récoltés dans des champs de haricots et de maïs cultivés en culture intercalaire étaient les moins endommagés.

INTRODUCTION

The common bean weevil, *Acanthoscelides obtectus* (Say), is widely distributed throughout sub-tropical and tropical regions and causes significant losses to beans in storage. Infestation often begins in the field and damage continues and intensifies during storage (Silim, 1990; Giga and Chinwada, 1992). Adult females

oviposit in mature, dry pods (Huignard, 1979; Thiery and Jarry, 1985). Although it is generally known that infestation begins in the field, there is a lack of information on the most susceptible pod stage, relationship between bruchid damage and other pod pests, bruchid carry-over from the field into storage, and pest management strategies. Studies were therefore conducted at Kawanda Agricultural Research Institute (KARI) to establish the susceptibility of pods to *A. obtectus* at different stages of development and the effect of chemical insecticides, bio-pesticides, and cropping systems on *A. obtectus* field infestations. The study was conducted for two seasons.

OBJECTIVES

The objectives of the study were

- to determine the most susceptible stage of pod maturity to *A. obtectus* infestation and damage in the field
- to evaluate the efficacy of candidate botanicals, synthetic insecticides, and *Beauveria bassiana* on *A. obtectus* field infestations
- to determine the influence of inter-cropping beans with maize on *A. obtectus* field infestation
- to determine the level of bruchid carry-over from the field

MATERIALS AND METHODS

Experimental plots were established at KARI. Bean variety K20 was used exclusively and the recommended agronomic practices (i.e., planting density of 50 x 10 cm, weeding, blanket treatment of floral and foliage pests using synthetic insecticide) were observed.

Field population build-up of A. obtectus

To determine the onset of bruchid infestation in the field, sticky-baited, sticky non-baited, and water traps were used. The sticky traps measured 30 cm long, 15 cm wide, and 15 cm high and were deployed at a height of about 25 cm from the ground to correspond to the different pod development stages. Thirty whole bean seeds were placed on the sticky matrix of the trap as bait. The water traps were yellow disc plastic plates filled with 400 ml of water and raised 5 cm from the ground by use of wooden block. The traps, including water traps, were randomly placed in the bean field at 50% flowering. The bean plots measured 12 m x 12 m and replicated four times. The trapped insects were examined, identified, and counted. Comparisons of the number of bruchids trapped after data transformation by $\sqrt{(x+1)}$ at the different pod development stages were made by two-way analysis of variance.

Determination of field infestation by A. obtectus

Pods were picked at different development stages, put in cloth bags to ensure no cross-contamination after harvest, and separately sun dried. The samples were divided into lots of five pods and incubated under ambient conditions until adult emergence.

Effect of bio-pesticides and synthetic insecticides on field infestations

The effect of insecticides and bio-pesticides on *A. obtectus* field infestations, was determined by spraying beans on pre-determined regimes with different formulations of pure ingredients or mixtures of cow urine, *Phytolacca dodecandra*, *Tagetes minuta*, *Capsicum frutescens*, *Nicotiana tobacum*, a suspension of *Beauveria bassiana* spores, Ambush, and Fenitrothion 50% EC, plus controls (untreated beans).

The treatments were prepared as follows:

- **Urine-based concoction**, formulated by mixing 1 kg each of pounded *P. dodecandra*, *T. minuta*, *C. frutescens*, ash, 5 litres of cow urine, and 250 ml of liquid soap; the mixture was then fermented for one week, filtered, and used
- **Water-based concoction**, formulated as above with water substituted for cow urine
- **Phytolacca extract** (fresh), formulated by mixing 1 kg of pounded *P. dodecandra* with 250 ml of liquid soap and 2 litres of water and filtered

- **Tagetes extract** (fresh), formulated by mixing 1 kg of pounded *T. minuta*, 250 ml of liquid soap, and 2 litres of water and filtered
- **Tobacco extract** (fresh), formulated by mixing 1 kg of pounded tobacco, 250 ml of liquid soap, 2 litres of water and filtered
- **Synthetic insecticides**, Ambush and Fenitrothion 50% EC, were used at 1 litre/ha
- ***Beauveria bassiana* fungal spores**, formulated with 2 kg of coarse maize bran containing fungal spores, 250 ml liquid soap, 4 litres of water and filtered

Prior to application, the botanical extracts were mixed with water in the ratio of 1:4. Spraying was initiated at the pod-filling stage and was continued at weekly intervals five times. The bean plots measured 2 m x 4 m. At maturity, each plot was harvested, beans were sorted into categories of pods damaged by sucking bugs and/or pod borers and undamaged pods. Each category was counted and the percentage damage calculated. The pods were then returned to the main sample, sun dried, threshed, and packaged according to treatment into 500-gm samples, which were incubated until adult emergence.

Effect of inter-cropping maize with beans on A. obtectus field infestation

We investigated the influence of mixed inter-cropping, row inter-cropping, and sole-cropping systems on field infestations of *A. obtectus* in beans. The bean plots measured 7.6 m x 2.4 m. In mixed inter-cropping, beans were planted along maize rows with a spacing of 10 cm between plants within rows. For row inter-cropping, two rows of maize were sown 75 cm apart and 30 cm intra-row. Two bean rows were then sown in between the consecutive maize rows with 40-cm inter-row spacing and 10-cm intra-row spacing. In sole cropping, plant spacing was maintained at 30 cm x 10 cm. At maturity, beans were harvested, sun dried, threshed, bulked into 500gm samples according treatment, and incubated until adult emergence.

RESULTS

A. obtectus was present in the field as early as pod formation, and the population increased significantly as the pods matured. The pod stages most susceptible to *A. obtectus* were physiological and harvest maturity (table 1).

Table 1. Mean Numbers of *A. obtectus* Trapped in Sticky-Baited Traps and Adult Emergence, by Pod Development Stage

Pod development stage	Means of <i>A. obtectus</i> (1st Season)	Means of <i>A. obtectus</i> (2nd Season)
Trapped in sticky-baited traps, by pod development stage		
50% Flowering	1.00 ± 0.00 (0)	1.00 ± 0.00 (0)
Pod formation	2.22 ± 0.09 (4)	2.44 ± 0.41 (5)
Pod filling	3.30 ± 1.08 (10)	2.82 ± 0.41 (7)
Physiological maturity	4.99 ± 0.09 (24)	3.60 ± 0.92 (12)
Harvest maturity	6.07 ± 0.18 (36)	5.06 ± 3.11 (25)
CV (%)	6.56	11.40
LSD (<i>p</i> = .05)	0.36	0.52
Adult emergence, by pod development stage		
Pod formation	1.00 ± 0.00 (0)	1.00 ± 0.00 (0)
Pod filling	1.00 ± 0.00 (0)	1.00 ± 0.00 (0)
Physiological maturity	1.74 ± 0.86 (2.25)	1.00 ± 0.00 (0)
Harvest maturity	2.64 ± 0.41 (6)	1.87 ± 0.08 (2.5)
CV (%)	18.54	7.13
LSD (<i>p</i> = .05)	0.47	0.128

Note: Means of data are transformed using $\sqrt{x+1}$. Actual means are shown in parentheses.

The sticky-baited trap was the most effective in detecting bruchid populations in the field.

Ambush was the most effective treatment in reducing bruchid infestation in the field, indicated by the low carry-over populations in storage. Crude concoctions of tobacco and phytolacca in water and soap as surfactants, as well as *B. bassiana* fungal spores in water were quite effective in reducing *A. obtectus* infestations in the field (table 2).

Table 2. Effect of Botanicals, Synthetic Insecticides, and *B. bassiana* on Field Infestation and on Damage by Pod-Sucking Bugs and/or Pod Borers

Treatment	Means of emergent <i>A. obtectus</i> (1 st Season)	Means of emergent <i>A. obtectus</i> (2 nd Season)
Control (untreated)	34.00 ± 2.28	41.25 ± 4.25
Phytolacca + Tagetes (water)	24.50 ± 2.24	27.25 ± 1.37
Phytolacca + Tagetes (urine)	14.00 ± 0.92	22.75 ± 2.14
Tagetes	22.00 ± 1.29	25.00 ± 0.96
Phytolacca	11.50 ± 1.71	14.25 ± 1.32
<i>B. bassiana</i>	10.50 ± 0.65	17.50 ± 1.04
Fenitrothion	9.50 ± 0.65	22.75 ± 2.14
Tobacco	6.25 ± 0.86	11.75 ± 0.86
Ambush	4.00 ± 0.96	4.75 ± 1.25
CV (%)	19.49	18.85
LSD ($p = 0.05$)	4.31	5.66
	Percent damage by pod borers 1 st Season)	Percent damage by pod borers (2 nd Season)
Control (untreated)	8.66 ± 0.22	6.53 ± 0.38
Phytolacca + Tagetes (water)	7.01 ± 0.02	5.06 ± 0.26
Phytolacca + Tagetes (urine)	6.17 ± 0.45	4.67 ± 0.06
Tagetes	6.64 ± 0.40	4.71 ± 0.34
Phytolacca	5.58 ± 0.21	3.35 ± 0.19
<i>B. bassiana</i>	6.12 ± 0.10	4.59 ± 0.07
Fenitritihion	4.89 ± 0.14	4.81 ± 0.18
Tobacco	5.47 ± 0.23	3.98 ± 0.07
Ambush	4.76 ± 0.19	3.24 ± 0.10
CV (%)	8.42	9.83
LSD ($p = 0.05$)	0.76	0.65

Note: Means of data are transformed using $\sqrt{x+1}$. Actual means are shown in parentheses.

There was a highly significant ($p < .05$) and positive relationship between adult emergence of *A. obtectus* and pod-sucking bugs and/or pod-borer damage ($r = 0.926; 0.892; n = 30$) during both seasons, suggesting that pod damage by borers and/or sucking bugs encourages field infestations (table 2)

There was a significant difference ($p < .05$) between the different cropping patterns in levels of bruchid infestation. Beans that were harvested from the mixed inter-crop with maize were the least damaged, compared to the row inter-cropped and sole-cropped beans (table 3).

Table 3. Effect of Cropping System on Emergence of adult *A. obtectus*

Cropping System	Means of emergent <i>A. obtectus</i> (1 st Season)	Means of emergent <i>A. obtectus</i> (2 nd Season)
Sole cropping	30.00 ± 2.49	24.50 ± 5.84
Row inter-cropping	10.25 ± 1.18	19.25 ± 4.35
Mixed inter-cropping	2.25 ± 2.49	2.50 ± 0.65
CV(%)	22.29	38.90
LSD ($\rho = .05$)	5.46	10.38

Note: Means of data are transformed using $\sqrt{(x+1)}$. Actual means are shown in parentheses.

DISCUSSION

The presence of *A. obtectus* in the field was determined as early as the pod-formation stage, and its population increased with the subsequent development stages. The stage most susceptible to *A. obtectus* was at physiological and harvest maturity, possibly due to the presence of cracks and crevices on the pod where the weevil can oviposit, and the seeds are at the right stage to support development.

The results indicated that field application of chemical insecticides (Ambush and Fenitrothion 50% EC), tobacco, and phytolacca was very effective in reducing storage damage from *A. obtectus*. This confirms earlier findings by Huignard (1979) and Thiery and Jarry (1985) that *A. obtectus* infestations are mostly of field origin and can therefore be greatly reduced by field applications of insecticides. McIndoo (1945) noted that an extract of tobacco leaves can control insect pests on crops. The major active biological ingredient in tobacco is nicotine.

Mixed inter-cropping of beans with maize reduces field-to-storage transfer of *A. obtectus*. It is possible that maize, which is a non-host crop for the pest, may physically interfere with the ability of the pest to find its host. The success inter-cropping could also be attributed to pest evasion, from either visual or tactile cues, or the effect of shading. It could also be due to the reduced number of host plants in the mixture.

RECOMMENDATIONS AND CONCLUSION

It is recommended that the promising methods achieved on-station be evaluated under farmer-managed field conditions.

It is suggested that small-scale, subsistence farmers emphasise botanicals other than synthetic insecticides, which are difficult to procure, apply, and protect oneself against.

In conclusion, more investigation is needed for the mechanism and mode of action of the bio-rationals and the effects of cultural practices in combination with bio-rational applications for *A. obtectus* field infestations.

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L'UTILISATION DES POUDRAGES DE PLANTES MÉDICINALES DANS LA LUTTE CONTRE LES BRUCHES DU HARICOT AU KIVU

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RÉSUMÉ

Au Kivu, en République Démocratique du Congo, les bruches du haricot sont les ravageurs les plus nuisibles aux graines de haricot stockées. Les méthodes efficaces en usage impliquent l'utilisation des insecticides. Cependant plusieurs insecticides sont actuellement prohibés et ne sont pas accessibles aux petits fermiers du Kivu. D'où la recherche de solutions alternatives. Des plantes médicinales à propriétés insecticides ont été testées au laboratoire, en 2001 à Lwiro, afin de déterminer leur efficacité dans la lutte contre les bruches du haricot. Il s'est avéré que le mélange des poudres de plantes appliqué par les paysans du Kivu à la dose 200 g/kg de haricots est plus efficace encore que l'utilisation de la poudre d'une plante seule. Or la dose de 30 g de poudre de Maesa lanceolata suit de près cette dose dite « paysanne » : elle aussi permet de réduire considérablement la prolifération des insectes et, par conséquent, les pertes de poids des stocks, qui deviennent négligeables.

Mots-clés : Bruches du haricot ; lutte biologique contre les ravageurs/protection phytosanitaire ; poudrage de plantes médicinales insecticides ; Kivu, RD Congo

ABSTRACT

In the Kivu provinces in the east of the Democratic Republic of Congo, bruchid beetles form the most important post-harvest threat to beans. Methods for controlling bean weevils generally involve insecticides, some of which, however, are currently prohibited or inaccessible to the region's smallholder farmers. In 2001, as part of their search for alternative solutions, scientists at the Lwiro Research Centre carried out laboratory tests using a number of local medicinal plants with insect-repellent qualities to assess their effectiveness as a pest-control tool. A mix of plant powders used by local farmers (200 g/ kg beans) proved to be more effective than applying the powder of a single plant. However the 30 g/kg dose of Maesa Lanceolata plant powder comes a close second to the 'farmers' dosage': it greatly reduces the emergence of bruchids, and any loss of stored bean stocks becomes insignificant.

Keywords: Bruchid beetles (bean weevils); integrated pest management; medicinal, insect-repellent plant powders; Kivu, DR Congo

INTRODUCTION

En Afrique centrale, australe et orientale, le haricot commun (*Phaseolus vulgaris* L.), principale légumineuse cultivée pour ses graines, est consommée par 80 % des communautés humaines. Denrée peu onéreuse, le haricot couvre plus de 11 % des besoins en énergie alimentaire quotidiens des populations tant rurales qu'urbaines, et 22 % des besoins en protéines. Il joue donc un rôle important dans l'économie ménagère, dans la formation du capital paysan et dans la sécurité alimentaire des populations: plus de 11 % du revenu annuel paysan provient de la vente du haricot (David et al., 2000).

Les agriculteurs de la région du Kivu en République Démocratique du Congo cultivent plusieurs variétés et types de haricot à des fins commerciales. Comme les prix sur les marchés sont bas durant les périodes de récolte (février-mars et mai-juin), les paysans emmagasinent leurs récoltes en attendant une hausse des cours. Ce stockage dure généralement de trois à cinq mois, période pendant laquelle le haricot stocké est souvent attaqué par des ravageurs, dont les plus importants sont les bruches (*Acanthoscelides obtectus* et *Zabrotes*

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subfasciatus) (Masolwa et Nchimbi, 1991). Ces bruches perforent les graines conservées et abîment ainsi leur qualité commerciale (Appert, 1985; Autrique et al., 1987,1988; Allen et al., 1996; Ampofo et al., 1992; Ampofo, 1993, 1997; Cardona et al., 1992; Nahdy et Agona, 1993; Nahdy, 1994). En Afrique tropicale, les pertes causées par ces ravageurs sont estimées à 30–80 % (Delobel et Tran, 1993; Dent, 1991; Saxena, 1987).

Les scientifiques ont déjà développé et vulgarisé toute une gamme de méthodes et de techniques de lutte contre les bruches du haricot. Citons parmi celles-ci les insecticides de synthèse, l'hygiène des entrepôts, un séchage adéquat des graines avant le stockage, l'application de substances végétales (jus et huiles tels les huiles de neem, de ricin, de soja et de palme, le jus de banane, etc.), l'utilisation de substances minérales (latérites, sables, chaux, roches, cendres de bois, etc.) et enfin, le recours à des variétés résistantes aux coléoptères ennemis des stocks (Nahdy et Agona, 1993 ; Giga et Chinwade,1993; Sindibona et Kayitare, 1987; Kumar, 1991; Stoll, 1988; Gwinner et al.,1991; Ross, 1998). Or, en milieu rural, ces technologies bien développées et validées posent souvent un problème d'adoption et d'acceptabilité. Ainsi les insecticides de synthèse, bien qu'efficaces, ne sont pas disponibles ou bien coûtent trop cher. Certains d'entre eux sont de plus en plus prohibés : l'usage en est polluant, ils sont toxiques et donc nuisibles aux organismes et leurs environnements.

L'utilisation d'huiles végétales qui consiste à enrober les graines d'huile d'arachide ou de palme à raison de 5 ml/kg, s'est avérée très efficace contre les bruches. L'adoption de cette technologie en milieu paysan bute à un obstacle du fait qu'elle ne convient pas lorsqu'il s'agit d'emmagasiner de grandes quantités de denrées dans l'attente d'un prix rémunérateur sur le marché. Autre problème, les graines conservées de cette manière ont une faculté germinative très basse et nécessitent un temps de cuisson bien long. Les graines enrobées d'huile de palme deviennent souvent difficiles à vendre : elles rancissent et deviennent désagréables à consommer et, au marché, leur aspect extérieur détérioré déplaît à l'acheteur.

Il importe donc d'utiliser des technologies de lutte contre les bruches qui veillent à ce toutes les qualités du haricot soient préservées pendant la conservation. Les paysans du Kivu estiment que certaines plantes médicinales constituent une bonne solution. Nous avons procédé à dresser l'inventaire de ces plantes insecticides et insectifuges qu'utilisent les paysans, pour ensuite évaluer leur efficacité : notre but était de voir si leur qualités justifient la diffusion de technologies basées sur leur utilisation, à toute la communauté paysanne intéressée par le stockage du haricot à des fins de commercialisation.

Le présent article résume les résultats préliminaires d'une étude portant sur le potentiel de protection de poudrages de certaines plantes présumées insecticides. Après avoir préparé des poudres de ces plantes, les chercheurs les incorporées, à différentes doses, dans les semences stockées qui ont d'abord connu une infestation artificielle de ravageurs de stocks.

MATÉRIELS ET MÉTHODES

Planification des essais

L'expérience a été réalisée sous la forme de deux principaux essais menés au laboratoire d'entomologie agricole du Centre de Recherche en Sciences Naturelles de Lwiro dans la province du Sud-Kivu. Le premier essai s'est déroulé du 5 mai au 5 novembre 2000 et le deuxième du 5 janvier au 4 juin 2001. Le centre de Lwiro se situe sur les rives ouest du Lac Kivu, à 1 650 m d'altitude et à 40 km de la ville de Bukavu en territoire de Kabare. L'on y trouve un climat de type Aw3, climat tropical humide tempéré par l'altitude et caractérisé par deux saisons : une saison pluvieuse de neuf mois (septembre–mai) et une courte saison sèche (juin–août). Le régime pluviométrique est bimodal, la première période allant de septembre à novembre et la deuxième de mars à mai (Munyuli, 2001). La moyenne annuelle des pluies est de 1 600 mm, celle de la température est de 19⁰C, et l'humidité relative est en moyenne de 76 %. La région de Lwiro présente un relief montagneux, par endroits vallonné. Le sol est un ferrisol argilo-sableux, dérivant de roches sédimentaires, métamorphiques, cendrées volcaniques et d'alluvions récentes. On y cultive plusieurs cultures tropicales (haricot, manioc, et autres) et tempérées (blé, pomme de terre, etc.).

Le matériel utilisé

Les variétés

Pour le premier essai, nous avons testé les variétés haricot soja (G2828) et Kirundo (M'mpuyeye en langue vernaculaire). Pour le deuxième essai, nous avons utilisé la variété M'Mafutala et la variété VCB 81012.

Ces variétés sont parmi les plus cultivées et les plus vendues sur les marchés locaux. Les variétés Kirundo, VCB81012 et G2828 seraient plus sensibles aux attaques des bruches que la variété M'Mafutala. Les paysans

cultivent les variétés G2828 et M'Mafutala pour assurer leur subsistance, alors que les variétés Kirundo et VCB 81012 sont davantage destinées au marché.

Les échantillons utilisés nous ont été fournis par Mr. Musakamba, à la station de l'INERA-Mulungu. Fraîchement récoltés, les échantillons n'avaient subi aucun traitement insecticide. Avant d'être utilisées, les graines ont d'abord été gardées au réfrigérateur (4°C) pendant 15 jours pour anéantir les infestations latentes.

Les plantes

Les paysans du Kivu se servent de 50 espèces végétales pour protéger leurs cultures. Parmi toutes celles-ci, nous avons choisi les plantes les plus communément acceptées par tous les paysans comme de puissants insecticides naturels, et en tout premier lieu les espèces *Tagetes minuta* (Asteraceae), *Agava americana* (Agavaceae), et *Maesa lanceolata* (Myrsinaceae).

Les insectes utilisés

Les insectes utilisés sont de souche locale, issus d'un élevage au laboratoire à partir de populations mères récoltées dans les stocks en milieu rural. *Acanthoscelides obtectus* a été élevé sur le haricot suivant la méthode proposée par Valerie Wright et al. (in Sindibona et Kayitare, 1987). Les insectes ont été préalablement sexés, à l'aide d'un au microscope binoculaire, selon la méthode de Perris (cité in Kumar, 1991 et Sindibona et Kayitare, 1987).

Matériel et conditions de stockage

Nous avons conservé les graines dans des sachets désinfectés, qui ont ensuite été enfremés dans des boîtes en plastique (20 x 20 x 8 cm) couvertes d'un tissu en nylon et d'un couvercle perforé. Ces boîtes ont été placées dans un local du laboratoire même et gardées à une humidité relative moyenne de 76 % et une température moyenne de 22,5°C.

Planification de l'expérience et dispositif expérimental

Formulation des doses testées

En général, l'unité expérimentale était le sachet contenant 1 kg de graines placé dans la boîte en plastique décrite plus haut.

La récolte des plantes s'est faite à la machette, dans la région de Lwiro : toutes les parties coupées (écorces, feuilles, tiges, etc.) ont été séchées à l'air libre dans le séchoir de l'insectarium de la section d'entomologie du CRSN-Lwiro.

Après un séchage qui a duré quatre semaines, les plantes ont été pilées pour obtenir des farines granuleuses que l'on a ajoutées au contenu des sachets, en doses croissantes—0 g (témoin), 10 g, 20 g, 30 g de poudre de chacune des plante, et cela donc par unité de 1 kg de graines conservées. Une balance de précision a permis de relever les différentes pesées à 100 g près.

Aux traitements énumérés ci-dessus, nous avons associé une autre dose, dite la « dose paysanne ». En effet, lors des nos enquêtes menées en milieu paysan, nous avons découvert que des « brigades de recherche paysanne » s'occupaient à tester l'application d'une dose de 200 g de poudre de plantes mélangées pour 1 kg de haricots qui, nous assuraient ces paysans-chercheurs, était efficace contre les bruches. La dose en question contient un mélange de poudres de toute une gamme des plantes (de 14 à 20 plantes). Voici les noms des principales plantes utilisées :

- | | |
|--|--|
| 1. <i>Tagetes minuta</i> (Asteraceae) | 12. <i>Phytolacca dodecandra</i> (Phytolacaceae) |
| 2. <i>Agava americana</i> et <i>Agava sisalana</i> (Agavaceae) | 13. <i>Eucalyptus</i> spp. |
| 3. <i>Artemisia annuata</i> (Asteraceae) | 14. <i>Cupressus</i> spp. |
| 4. <i>Maesa lanceolata</i> (Myrsinaceae) | 15. <i>Piper guineense</i> (Piperaceae) |
| 5. <i>Tithonia diversifolia</i> (Asteraceae) | 16. <i>Nicotiana tabacum</i> (Solanaceae) |
| 6. <i>Capsicum frutescens</i> (Piperaceae) | 17. <i>Ipomoea involucreata</i> (Convolvulaceae) |
| 7. <i>Chenopodium ugandae</i> | 18. <i>Pentas longiflora</i> (Rubiaceae) |
| 8. <i>Mentha aquatica</i> (Lamiaceae) | 19. <i>Palisota schweinfurthii</i> (Commelinaceae) |
| 9. <i>Vernonia amygdalina</i> (Asteraceae) | 20. <i>Darura stramonium</i> (Solanaceae) |
| 10. <i>Tetradenia riparia</i> | 21. <i>Haummanistrum galeopsifolium</i> L. |
| 11. <i>Tephrosia vogelii</i> | (Lamiaceae) |

Dispositif expérimental

Comme nous l'avons indiqué pour le stockage, nous avons placé des sachets stérilisés remplis de graines de haricot dans des boîtes en plastique achetées au marché local, puis lavées et stérilisées (à la chaleur sèche). Les boîtes ainsi placées au laboratoire contenaient chacune 1 kg de haricot, un sachet pour chaque variété. Le poudrage des graines eut lieu une semaine après leur placement dans les sachets et chaque unité fut artificiellement infestée par un nombre donné de couples d'imagos. Le lâcher des insectes (imagos âgés de 4 jours) est intervenu 3 semaines plus tard, à raison de 10 couples sexés (premier essai) et 5 couples sexés (deuxième essai). Le dispositif expérimental monté au laboratoire était un dispositif en blocs casualisés. Le nombre de boîtes était de sept pour chaque traitement et chaque traitement a été répété sept fois. Le remuage des produits stockés n'a pas été jugé nécessaire.

Paramètres mesurés

Après sept mois de conservation dans ces conditions, nous avons procédé au dépouillement de données, en prélevant, pour chaque unité expérimentale (boîte), les paramètres suivants:

- Le nombre d'insectes vivants ayant émergé (**N**)
- Le nombre des graines trouées ou attaquées (**Na**)
- Le nombre des graines saines (**Ns**)
- Le poids des graines trouées (**Pa**)
- Le poids des graines saines (**Ps**)

Traitement des données

Un comptage à vue des insectes présents dans les sachets a permis d'aboutir à un nombre moyen d'insectes vivants ayant émergé après la période de stockage.

À l'aide de la formule proposée par Golob (Sindibona et Kayitare, 1987, Kumar, 1991, Dent, 1991), l'on a calculé le pourcentage de perte de poids (**P%**) :

$$P (\%) = \frac{(Na \times Ps) - (Ns \times Pa)}{Ps (Na+N_s)}$$

Les résultats obtenus, à savoir les nombres moyens d'insectes vivants et le pourcentage moyen de pertes de poids, ont fait l'objet d'une analyse statistique (en utilisant le programme Genstat computer package).

RÉSULTATS ET DISCUSSION

Les deux tableaux placés plus bas présentent les résultats obtenus aux deux essais menés pour étudier l'effet de l'enrobage des graines de haricot par les poudres des plantes médicinales, sur le pourcentage de perte de poids et le nombre des imagos émergés de la bruche *Acanthoscelides obtectus*. Les moyennes ont été calculées à partir des données brutes recueillies pour les sept répétitions. Une analyse statistique de ces résultats a été effectuée en appliquant la méthode d'analyse de la variance complète après une transformation des données. Pour chaque plante testée, les calculs statistiques décèlent une différence significative ($P = 0,005$) entre les traitements (doses) considérées.

Le premier essai (tableau 1) fut mené du 5 mai au 5 décembre 2000. Le nombre de couples d'imagos lâchés au départ dans chaque unité expérimentale fut de 10.

Au bout de sept mois de stockage, on nota que le nombre d'insectes vivants ayant émergé était considérablement plus élevé dans les sachets témoins que dans les autres traitements. Le tableau 1 montre en effet que par rapport aux témoins (M0, A0 et T0), ce sont surtout les doses M2 et M3 de poudre de *Maesa lanceolata* (20–30 g par kilogramme de graines de haricot) et la dose paysanne de poudre mélangée (200 g/kg de haricot) qui ont fortement réduit le développement des insectes : sept mois après l'infestation originale par les 10 couples par unité expérimentale, le nombre moyen d'imagos est de 2,65 pour les traitements M3 (30g.) et de zéro suite à l'application du Mélange (200g), alors que, pour le témoin, la moyenne correspondante M0 est de 194,5 (tableau 1). Les farines granuleuses de *Maesa lanceolata* et le mélange de la dose paysanne ont eu le plus grand effet et réussissent le mieux à conserver les graines contre les bruches. Il convient de noter que cette réduction du nombre d'imagos émergés varie clairement d'une variété de haricot à une autre et que la réduction la plus sensible (1,9) a été obtenue avec la variété G2828, le haricot soja.

Pareillement, le tableau 1 montre que le pourcentage de perte de poids est considérablement plus important dans le cas des sachets témoins que pour ceux des autres traitements. En ralentissant fortement la

Tableau 1. Effet du poudrage des graines de haricot sur le ravageur *Acanthoscelides obtectus* : résultats du premier essai (7 mois ; 10 couples d'imagos)

Plantes	Dose (g)	Traitement	Variété + poids initial des graines					
			G2828 h.soja : 1kg n=2000 graines		Kirundo : 1 kg n=1366 graines		Moyenne générale	
			P(%)	N	P(%)	N	P(%)	N
<i>Tagetes minuta</i>	0	T0	81,00	234,00	96,00	306,00	88,50	270,00
	10	T1	77,00	151,00	83,00	170,00	80,00	161,50
	20	T2	51,00	87,00	66,00	110,00	58,50	95,00
	30	T3	30,00	65,00	28,00	66,00	29,00	65,50
<i>Agava americana</i>	0	A0	94,00	190,00	89,00	316,00	91,50	250,00
	10	A1	59,00	79,00	46,00	88,00	52,50	83,50
	20	A2	10,60	21,00	14,00	26,00	12,30	23,50
	30	A3	4,70	10,60	7,10	19,50	5,80	15,05
<i>Maesa lanceolata</i>	0	M0	91,00	174,00	92,00	215,00	91,50	194,50
	10	M1	21,00	45,00	19,00	66,00	20,00	55,50
	20	M2	1,70	6,50	1,90	4,50	3,60	5,50
	30	M3	0,40	1,90	1,16	3,40	0,75	2,65
Mélange	200	MDP	0,03	0	0,05	0	0,04	0
SED			0,07	0,94	0,02	2,67		

Légende:

P(%) : pourcentage de perte de rendement

N : nombre moyen des imagos émergés après 4 mois de stockage

n : nombre initiale des graines

Mélange : « dose paysanne » composée des poudre de plusieurs plantes (utilisée au Kivu)

SED: Erreur standard d'une différence entre les moyennes des traitements

prolifération des bruches, l'apport de la poudre de *Maesa lanceolata* (dose M3 surtout) et du Mélange(dose paysanne) a entraîné une perte de poids bien moins importante du haricot stocké : le pourcentage de perte du rendement est de l'ordre de 0,75 % pour le traitement M3 et de 0,04 % suite à l'application Mélange, alors qu'il était de 91,5 % pour le témoin M0. Cela nous permet de conclure que les traitements M3 et Mélange présentent une solution de rechange économiquement avantageuse (par rapport aux insecticides de synthèse) pour les producteurs de semences souhaitant stocker leurs semences dans l'attente d'un prix rémunérateur.

Le second essai (tableau 2) fut mené du 5 janvier au 4 juin 2001. Cette fois-ci le nombre de couples d'imagos lâchés par unité expérimentale fut 5.

D'une façon générale, le tableau 2 montre la même tendance que le tableau 1.

La dose de 30 g de poudre de *Maesa lanceolata* et la dose paysanne permettent une fois de plus de réduire considérablement la prolifération des insectes et, par conséquent, les pertes de poids des stocks sont négligeables. Le pourcentage moyen de ces pertes est 0,6 % pour le traitement M3 et 0,005 % pour l'application du Mélange. Le nombre d'imagos ayant émergé était de 1,13 (M3) et 0 (Mélange).

Dans la pratique, l'enrobage des graines en appliquant la dose de 30 g de poudre de *Maesa lanceolata* par kilogramme de graines signifie que, pour 100 kg de semences à conserver, le paysan aura besoin de 3 kg de poudre. À cette échelle relativement modeste, cela ne pose pas de problème. Pour obtenir 3 kg de poudre, le paysan devra abattre deux ou trois arbustes. *Maesa lanceolata* est encore une plante sauvage que l'on trouve actuellement dans les réserves forestières et aires protégées du Kivu. Si toutefois l'on souhaite prévenir l'abattage systématique et éviter la menace d'extinction des populations sauvages, il importera de domestiquer l'arbuste et de l'intégrer dans les agro-écosystèmes locaux des paysans.

Le problème se pose si l'on examine le cas de la « dose paysanne ». Nous avons vu que la brigade agricole des paysans de Katana avait découvert que l'incorporation d'une dose de 200 g de poudre de plantes mélangées à un kilogramme de graines de haricot, permettait de très bien maîtriser les bruches. Les deux essais que nous avons réalisés sur une année pleine nous ont conduits aux mêmes observations et conclusions. Or dans la pratique, une telle dose présente des difficultés. Un paysan souhaitant conserver

Tableau 2. Effet du poudrage graines de haricot sur le ravageur *Acanthoscelides obtectus* : résultats du second essai (6 mois ; 5 couples d'insectes par unité expérimentale)

.	Dose (g)	Traite ^{mnt}	Variété + poids initial des graines					
			M'Mafutala (1 kg) n=1809 graines		VCB81012 (1 kg) n=1721 graines		Moyenne générale	
			P(%)	N	P(%)	N	P(%)	N
<i>Tagetes minuta</i>	0	T0	49,00	77,00	56,90	65,00	48,00	71,500
	10	T1	19,00	59,00	25,70	83,00	17,50	71,000
	20	T2	8,00	27,00	19,10	47,00	13,50	37,000
	30	T3	5,50	1,70	15,50	27,10	10,50	22,500
<i>Agava americana</i>	0	A0	40,00	81,00	61,50	91,00	55,75	91,000
	10	A1	29,00	41,00	26,70	72,00	27,53	56,500
	20	A2	6,00	8,71	2,70	27,00	4,35	14,570
	30	A3	2,00	1,49	1,65	7,00	1,82	4,245
<i>Maesa lanceolata</i>	0	M0	46,00	81,00	24,10	51,00	30,00	66,000
	10	M1	17,10	45,00	5,50	24,00	11,30	34,500
	20	M2	0,56	1,60	0,70	1,50	0,63	1,550
	30	M3	0,08	1,20	0,04	1,06	0,60	1,130
Mélange	200	MDP	0,005	0	0,005	0	0,005	0
SED			0,94	0,07	0,035	1,27		

Légende:

P(%) : pourcentage de perte de rendement

N : nombre moyen des imagos émergés après 4 mois de stockage

n : nombre initiale des graines

Mélange : « dose paysanne » composée des poudre de plusieurs plantes (utilisée au Kivu)

SED: Erreur standard d'une différence entre les moyennes des traitements

100 kg de graines devra fabriquer 20 kg de poudre ; pour obtenir les ingrédients du mélange de poudres requis, il devra récolter des plantes sur une surface de plus d'un hectare ! Il n'est pas facile pour un paysan du Kivu de pouvoir consacrer un hectare de ses terres à la culture des plantes insecticides.

Autres plantes insecticides

L'usage des plantes médicinales dans la lutte contre les ravageurs des denrées stockées est une pratique courante en Afrique noire. De nombreux chercheurs africains s'intéressant à l'amélioration et à la rationalisation des pratiques paysannes de conservation des stocks avec les produits locaux, se sont efforcés d'inventorier les diverses pratiques et d'en évaluer l'efficacité dans différentes zones agro-écologiques de l'Afrique. Giga et Chinwada (1993) ont ainsi observé au Zimbabwe que la dose de 0,1 kg de neem (farine de feuilles et graines) par kilogramme de graines conservées permettait de réduire significativement le nombre d'imagos émergés et le pourcentage de perte de poids. Autre exemple, en Afrique occidentale : l'apport de l'écorce pulvérisée de *Khaya senegalensis* à la dose de 50 g/kg de niébé ou de mil conservé, permet une réduction sensible du nombre d'insectes émergés et une réduction de la perte de poids allant jusqu'à 0,56 % (Gwinner *et al.*, 1991). Par ailleurs, nombre d'études menées dans la région des Grands Lac (Rwanda, Burundi, etc.) ont déjà porté sur l'efficacité et la rémanence de feuilles ou d'inflorescences fraîches ou séchées de quatre plantes (*Ocimum kilimandascharium*, *Iboza riparia*, *Chenopodium schraderanum*, *Capsicum frutescens*) sur l'oviposition des femelles, le taux d'éclosion des œufs et le pourcentage de mortalité des larves et imagos de la bruche. Ainsi une étude menée au Rwanda en 1987 a permis de constater que des quatre plantes, seule *Iboza riparia*, était efficace. Utilisée sous forme de poudre séchée (doses de 5 g/kg de graines de haricot) cette plante entraînait un pourcentage de mortalité supérieur à 70 % (Ukiricho, 1987). Ces résultats corroborent les nôtres même si nous n'avions pas utilisé les mêmes plantes.

Il existerait plusieurs biopesticides naturels contre les ravageurs de stocks. Au Cameroun, Parth *et al.* (1990) ont démontré que *Ocimum suave* et *Cypripedium sp.* protégeaient très bien les graines de niébé stockées pendant plus de quatre mois contre les dégâts causés par les bruches *Callosobruchus maculatus* et *Acanthoscelides obtectus*. En Afrique de l'Est, le neem (*Azadirachta indica*) utilisé sous différentes formes constitue

probablement le plus puissant insecticide végétal en cours de promotion par les scientifiques. Dans la région des Grands Lacs, *Ocimum sp* serait l'équivalent du Neem dans la protection du haricot contre les bruches.

Il faut noter cependant que toutes ces plantes performantes ne sont pas distribuées équitablement dans les biotopes et écosystèmes de l'Afrique. Par ailleurs, certaines plantes s'adaptent difficilement lorsqu'on les introduit dans un nouveau milieu qui est écologiquement différent du milieu d'origine (biotopes préférentiels). Une façon de contourner cet obstacle écologique peut être de chercher, à tout point de la terre, quels biopesticides locaux peuvent servir de substitut aux pesticides de synthèse ou pour remplacer des biopesticides performants mais importés d'ailleurs.

Pour ce qui est de la maîtrise des bruches du haricot, *Maesa lanceolata* s'avère être une solution fort adéquate répondant aux préoccupations évoquées précédemment. Cette plante est localement trouvable au Kivu. Le fait qu'elle se reproduit par boutures et par graines présente un double avantage au niveau de la propagation de ce qui semble, actuellement, être l'insecticide végétal le plus puissant au Kivu.

CONCLUSION ET SUGGESTION

Nos recherches avaient pour objectif de connaître la dose optimale d'application de certaines poudres de plantes médicinales pour conserver des graines de haricot, notamment des farines granuleuses d'*Agava americana*, *Maesa lanceolata* et *Tagetes minuta*. Un deuxième objectif était de vérifier l'efficacité de la « dose paysanne » employée localement pour protéger les stocks contre les bruches du haricot emmagasiné.

Les résultats de nos travaux nous ont permis de tirer les conclusions suivantes :

- Les poudres de *Maesa lanceolata* réduisent significativement l'émergence des imagos dans les stocks de haricots et font ainsi baisser le pourcentage de perte de poids. Nous avons vu, en effet, qu'à des doses d'application de 20–30 g/kg de graines de haricot conservé pendant cinq mois ou plus, les poudres de *Maesa lanceolata* ralentissent considérablement le développement de la population des charançons. Le nombre d'imagos émergés a été de 1,13 au deuxième essai et de 2,65 au premier, différence qu'il faut comparer au résultat du témoin M0 du premier essai, à savoir 194,5 imagos. L'amointrissement du pourcentage de perte de poids était de l'ordre de 0,75 % (1^{er} essai) et 0,6 % (2^{ème} essai).
- Le traitement par l'application de la dite « dose paysanne »—mélange de plusieurs plantes que l'on appliqué à raison de 200 g de poudre par kilogramme de graines—est très efficace contre les bruches.

Nous reconnaissons que nous n'avons pas encore pu mettre en évidence ni expliquer les comportements et les réactions des ravageurs face aux différentes variétés de haricots et face aux doses croissantes de poudres des plantes. De même, les mécanismes d'action en jeu qui font que les poudres freinent le développement normal des populations de charançons sur le haricot stocké constituent encore un domaine à élucider.

La recherche est donc mise au défi d'isoler puis de caractériser les principes actifs de *Maesa lanceolata*, qui, une fois déterminés, devraient pouvoir servir à la fabrication de biopesticides simples, moins coûteux, biodégradables et utilisables par le petit producteur souhaitant mieux protéger ses graines stockées contre les ravageurs.

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SESSION 6
SEED-PRODUCTION SYSTEMS

ACCESS TO SEED, A FACTOR IGNORED IN CROP VARIETAL ADOPTION STUDIES: A CASE STUDY OF BEANS IN TANZANIA

Soniia David, Leonard Mukandala, and January Mafuru

ABSTRACT

Few studies on the adoption of new crop varieties report on farmers' access to seed and the implications for adoption, in terms of the decision to try a new variety and to continue growing it season after season. By exploring the low adoption of a modern bean variety in 1998 in Bukoba District, Tanzania, this paper examines the importance of seed availability for the adoption of new crop varieties. The findings suggest that two factors accounted for low adoption of the variety, Lyamungu 90, at the time of the study: farmers' limited access to seed coupled with a failure to promote the variety, and low and fluctuating market demand, which was partly caused by scattered seed distribution. The paper shows that failure to consider seed availability as an adoption constraint may lead to the erroneous conclusion that farmers reject new varieties solely on the merit of their characteristics and performance. Seed dissemination strategies aimed at small, resource-poor farmers should re-supply seed over several seasons until new varieties become fully established in local seed networks and markets.

RÉSUMÉ

Peu d'études sur l'adoption de nouvelles variétés végétales examinent le problème de l'accès aux semences pour les cultivateurs et des incidences au niveau de l'adoption variétale, qu'il s'agisse de la décision d'essayer une nouvelle variété ou du choix d'en poursuivre la culture durant plusieurs saisons. En se penchant sur le faible taux d'adoption en 1998 d'une variété moderne de haricot dans le District de Bukoba, en Tanzanie, les auteurs de ce document examinent l'importance de la disponibilité des semences pour l'adoption de nouvelles variétés végétales. Les résultats suggèrent que deux facteurs expliquent l'adoption restreinte de la variété Lyamungu 90 : d'une part l'accès limité des cultivateurs aux semences, conjugué à une promotion insuffisante de la variété, et d'autre part la demande faible et fluctuante sur le marché, due en partie à la diffusion éparse des semences. L'étude montre que le fait d'ignorer le manque de disponibilité des semences en tant qu'obstacle à l'adoption peut conduire à conclure à tort que les cultivateurs rejettent de nouvelles variétés uniquement en raison de leurs caractéristiques et de leurs performances. Les stratégies de diffusion semencière axées sur les petits exploitants pauvres devraient fournir des semences pendant plusieurs saisons jusqu'à ce que les nouvelles variétés aient trouvé leur place dans les réseaux et les marchés locaux de semences.

Keywords: adoption of modern crop varieties, beans, seed systems, technology dissemination, Eastern Africa, Tanzania

INTRODUCTION

Much attention has been paid in the economic literature to the socio-economic and farm determinants of technology adoption (see Feder et al., 1985, and Feder and Umali, 1993, for authoritative reviews). The sociological literature goes further to emphasise the importance of access to information (Rogers, 1962; see Agarwal, 1983, for a good review). These two paradigms assume that technological innovations are always appropriate for farmers. A more recent paradigm (the adopter-perception model) questions that assumption by postulating the importance of farmers' perceptions of the attributes of technology and innovation conditions (i.e., the problem to be solved by new technologies) for adoption decisions (Adesina and Zinnah, 1993; Adesina and Baidu-Forson, 1995; Sanginga et al., 1999).

All three models implicitly assume that farmers have access to new technologies, provided they have cash or credit. Few studies on the adoption of new crop varieties report on farmers' access to seed and the implications

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for adoption, in terms of the decision to try a new variety as well as to continue growing it season after season. This seemingly obvious point is noted by Feder and colleagues (1985: 280), who point out that ‘a sound [adoption] study should determine whether behavior is supply constrained’. One reason for lack of attention to issues of seed supply may be because the adoption literature is largely dominated by studies conducted in Asia during the Green Revolution (1960s to early 1980s), where extension systems and the agricultural infrastructure (e.g., input supply system) were relatively well endowed. Second, the literature on technology adoption in Africa is predominantly concerned with maize (the single most important food crop on the continent), a crop that has relatively few seed supply constraints because of the involvement of the formal seed sector, and in some cases, politically motivated, free seed distribution (Nkonya et al., no date; Gerhart, 1975; Marfo and Tripp, 1991; Smale et al., 1991; Nkonya et al., 1997). In the case of sorghum and millet, crops not supplied by the formal seed sector, concerns about seed supply may be mitigated by two factors: the importance of farmer seed exchange networks (Rohrbach, 1997) and, in Southern Africa, the effectiveness of seed dissemination through drought relief programs (Rohrbach and Mutiro, 1996).

For the most part, studies on the adoption of modern varieties of self-pollinating (e.g., rice, soybean) or vegetatively propagated crops (e.g., cassava) in Africa scarcely mention seed distribution activities and rarely investigate whether access to seed affects adoption (Poulson and Spencer, 1991; Adesina and Zinnah, 1993; Adesina and Baidu-Forson, 1995; Sanginga et al., 1999). Adoption studies on cowpea (Inaizumi et al., 1999), pigeonpea (Audi et al., no date), and beans (Sperling and Loevinsohn, 1993; David et al., 1997) provide a few notable exceptions. Yet, the literature on seed systems provides ample evidence of the difficulties small-scale African farmers have in obtaining and retaining seed. This problem is particularly acute for newly released modern varieties that are not yet fully established in local seed systems, and commercial varieties or crops that farmers do not commonly share free of charge (Cromwell, 1990; Almekinders et al., 1994; David and Sperling, 1999; David, 2000).

The seed supply dilemma for self-pollinating and vegetatively propagated crops and crops with limited seed demand (e.g., indigenous vegetables, forages, open-pollinated maize) has two dimensions. The first problem is how to ensure an initial supply of seed for newly released varieties, usually in the absence of a formal seed sector. Crops such as the common bean, sweet potatoes, and open-pollinated maize bring little profit to seed companies for several reasons: uncertain and fluctuating demand caused by competition from farm-saved seed (grain legumes, forages), low multiplication rates (grain legumes), transportation and storage difficulties (root and tuber crops, soybean), and strong regionally specific preferences (indigenous vegetables, beans). The second problem is farmers’ inability to retain seed of both traditional and modern varieties in the face of poverty and unfavourable agro-environmental conditions that cause them to eat or sell their seed, or to lose it in the field or during storage.

The objective of this paper is to explore the importance of seed availability for the adoption of new crop varieties. It argues that the omission of this variable may negatively bias investigations of varietal adoption. The specific case discussed here is the adoption of a modern bean variety, Lyamungu 90, in Bukoba District, western Tanzania. The rest of the paper is organised as follows. Section two provides a background to bean production in Bukoba District and describes the methodology used in the study. Section three presents the adoption findings, while section four discusses factors that contributed to low adoption of Lyamungu 90. The final section draws conclusions about seed dissemination strategies for enhancing adoption.

BEAN PRODUCTION IN BUKOBA DISTRICT

Bukoba District is located in Kagera Region, a major bean-producing region of western Tanzania. Beans play a major role in the domestic economy of the banana-coffee-based production system of the district and are grown as single varieties in mixed cropping systems during two growing seasons a year. The *vuli* season (September-November) is more favourable for bean production than is the *masika* season (March-May), when rainfall is heaviest and temperatures and light intensity are lower. The crop is grown in two distinct land-use patterns. The most important land-use type is *vibanja* (sing: *kibanja*) where beans are intercropped with permanent crops such as bananas (cooking, brewing, sweet) and coffee (mainly robusta) that are planted near the homestead. The second land-use type is *vikamba* (sing: *kikamba*) where beans are planted in pure stands or intercropped with annual crops such as sweet potatoes, maize, cassava, yams, sorghum, and groundnuts. Women provide most of the labour in bean production and play a key decision-making role.

In contrast with most Eastern Africa populations, the Haya, the dominant ethnic group, traditionally prefer small-seeded white bean varieties, which are eaten mashed with cooking bananas, sweet potatoes, or cassava. Beans became an important cash crop in high-potential areas of Bukoba District in the early 1990s as a result

of crop failure in drier parts of the country and increased demand from Rwandan refugees and other areas of the country (Nkuba et al., 1995). While all seed sizes are sold, small-seeded bean varieties have low demand and command a lower price than large-seeded varieties. Bean commercialisation has resulted in changes in farmers' varietal profiles and level of production, and has increased male involvement in bean production (Nkuba et al., 1995; Nkuba, 1996). With respect to varietal profiles, farmers grow small-seeded varieties¹ of all colours for home consumption and medium- and large-seeded varieties for sale. In general, the area planted to white-seeded varieties has decreased in favour of increased production of medium- and large-seeded brown and yellow varieties.

Our survey results show that land-use patterns also reflect a dualistic production strategy: nearly 60% of surveyed households used beans produced on *kibanja* for food only, while 22% of households grew beans on *kikamba* mainly for sale. Surveyed farmers generally sowed small- and medium-seeded varieties on *kibanja* and all seed types on *kikamba*.

Large-seeded Calima² types (referred to collectively by farmers as 'Rosecoco') were probably first brought to the Kagera Region from Uganda around the late 1980s and were quickly adopted in some areas (e.g., Karagwe District) as a cash crop (Ndege et al., 1995). Calima types were probably first brought to Bukoba District from Karagwe District in the early 1990s. It is important to note that Lyamungu 90, a Calima seed type, is easily distinguishable from Rosecoco by its distinctive shape.

The introduction of Lyamungu 90 to Bukoba District

Lyamungu 90 (G5621) was developed for the mid-altitude zones of Tanzania and officially released in 1990. It has a bush growth habit, matures quickly (70–89 days), and cooks in a relatively short time (48 minutes). The variety did not significantly out-yield local varieties in on-farm trials—770 kg/ha on *vibanja* fields and 742 kg/ha on *vikamba* fields (Mukandala et al, 1994)—but because of its large seed size, researchers expected it to be taken up as a cash crop grown on *kikamba* (Mukandala et al, 1994; Nkuba et al., 1995). In 1992 bean researchers distributed 120 kg of Lyamungu 90 free of charge to 240 farmers in 15 villages in Bukoba, Muleba, and Karagwe Districts. In Bukoba District, 69 kg of seed was distributed to 138 households in seven villages in three diverse bean-production areas (high, medium, and low potential). Households were selected by extension agents and each received 500 grams of seed. Farmers also had access to seed of the new variety through on-farm varietal trials conducted between 1988 and 1990, distribution efforts by farmer research groups (established by researchers in 1995), and district rural-development programs. A 1994 survey (Mafuru et al., 1996) showed that 67% of 48 seed recipients in Bukoba were still sowing the variety two years after they were first given seed.³ Although an earlier Calima variety, Lyamungu 85 (released in 1985), was also tested in Bukoba and was probably taken up by some farmers, this study does not distinguish between the two varieties due to their similar characteristics and performance.

Methods

This paper draws on results from a formal survey of 300 randomly selected households conducted in February 1998. The purpose of the survey was to assess the adoption of Lyamungu 90 six years after the seed-distribution exercise. Nine villages in three agro-ecological zones (high, medium, and low) were sampled. To assess the spread of the variety, in each zone, the survey was conducted in a village where seed had been distributed directly or through on-farm varietal trials ('participating village') and in two neighbouring villages ('non-participating village'). Half of the sample was drawn from participating villages. Enumerators were trained to distinguish between Lyamungu 90 and local Calima types (Rosecoco). Adoption of Lyamungu 90 was verified by visual identification from a sample of seed obtained from each surveyed household. *Vuli* 1997 and 1996 were used as reference seasons for questions related to production and marketing, respectively.

Interviews were mainly conducted with women farmers (65%) and couples (21%). On the basis of community-derived wealth indicators, the majority of households fell in the average wealth category (68%); 15% were above average, 15% were poor, and 2% were wealthy.

¹ Small-seeded bean varieties inherently have a higher yield potential than large-seeded varieties.

² Calima types have large, dark-red, mottled seeds.

³ Because this study did not distinguish between Lyamungu 90/85 and other existing Calima seed types (i.e., Rosecoco), it is likely that the adoption rate for Lyamungu 90 was over-inflated.

Due to the small number of adopters, results from multivariate analysis were not meaningful. Descriptive statistics were therefore used to explain adoption trends.

ADOPTION OF LYAMUNGU 90

Although a quarter (26%) of the 300 households surveyed had ever sown Lyamungu 90, a scant 33 (11%) still had seed of the variety at the time of the survey and therefore could be considered as adopters (figure 1). Ten of these households were headed by women. Notably, in most households, the decision to adopt Lyamungu 90 was made by women. Thirty-two of the 33 adopters sowed Lyamungu 90 in *vuli* 1997, but significantly, only five had seed consisting purely of Lyamungu 90; the rest had a mixture of Lyamungu and other Calima types.⁴ Farmers who had never grown Lyamungu 90 were not asked whether they had heard about or knew the variety, as few (16%) could distinguish Lyamungu 90 from Rosecoco when shown samples of the two.

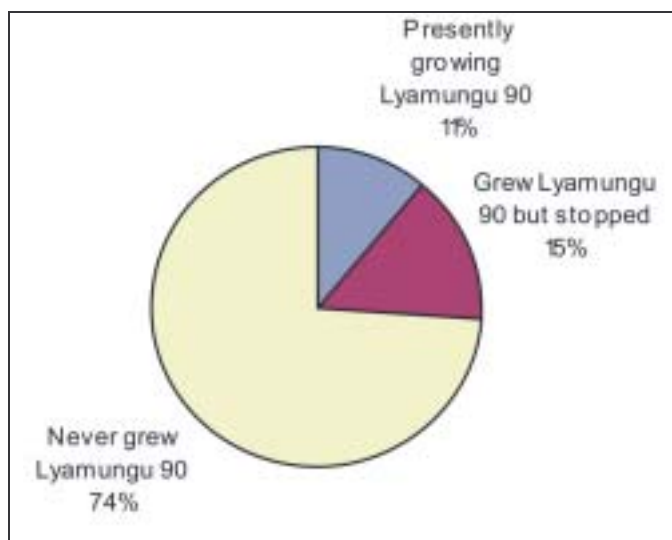


Figure 1. Adoption of Lyamungu 90, 1998 (n=300)

Fifteen percent of surveyed households had previously sown Lyamungu 90 and/or another Calima variety but had stopped by the time of the survey (figure 1). Dis-adopters grew the new variety for only a short time: an average of 1.5 seasons on *kibanja* and 1.4 seasons on *kikamba*. The high proportion of accidental seed loss suggests that among nearly 60% of farmers who tried Lyamungu 90, dis-adoption was not related to negative perceptions of the variety's characteristics or performance (table 1). It is significant, however, that the single most important reason for dis-adoption, cited by 22% of dropouts, was poor marketability. The majority (63%) of dis-adopters came from participating villages; over half (57%) lived in high-potential bean-growing areas.

Although Lyamungu 90 had been available in the study areas for six years, most adopters had limited experience with the variety. Thirteen of the 28 households had sown Lyamungu for one season on *kibanja*, 11 for two to three seasons and four for more than three seasons. Households in high-potential areas had sown the variety on *vibanja* fields for significantly more seasons than households in other zones (an average of three times, compared to two times for medium- and low-potential areas).

Adoption was highest in medium- and high-potential areas of the district (33% and 39%, respectively, compared with 27% in low-potential areas) and in participating villages (15% compared to 7% in neighbouring villages). Eighteen percent of adopters had hosted on-farm varietal trials. However, there was little difference in the area planted to beans or to Lyamungu 90 by adopters in participating and non-participating villages. Adopters did not differ significantly from the wider sample in terms of socio-economic characteristics, although they tended to be older and more experienced farmers (table 2).

In *vuli* 1997, 25 of the 32 adopters who grew Lyamungu 90 that season sowed the variety only on *vibanja* fields. Three households sowed the variety on both *kibanja* and *kikamba* and four households sowed it exclusively on *kikamba*. On average, farmers sowed 5 kg (ranging from 250 g to 20 kg) of Lyamungu 90 on

⁴ For simplicity, in this paper we refer to a mixture of both Lyamungu 90 and other Calima types as Lyamungu 90 or Calima types.

Table 1. Reasons for Dis-Adoption of Lyamungu 90/Calimas (n=46)

	Percent		Percent
Accidental loss (n=27):	58	Intentional (n=19):	41
Ate all seed	20	No market	22
Crop failure	17	Variety not tasty	11
Seed destroyed by storage pests	15	Low yields	6
Sold all seed	4	Little seed, so ate it	4
Other	2	Not disease resistant	4

Note: Totals for specific reasons do not add up to 100% due to multiple answers.

Table 2. Socio-Economic Characteristics of Adopters and Non-Adopters

Variable	Adopters (n=33)	Non-adopters (n=267)
Total bean area, <i>vuli</i> 1997	0.44 ha	0.44 ha
Produce beans on <i>kibanja</i> mainly/only for food	100%	96%
Average/above-average wealth	85%	82%
Female-headed households	30%	25%
Age of household head	54 years	49 years
Farming experience	30 years	28 years

0.06 ha of *vibanja* fields. Mean amounts of Lyamungu 90 sown on *kikamba* were similar: 6 kg (a range of 1 kg to 20 kg) on 0.05 ha of *vikamba* fields. On average, adopters sowed 8 kg of the predominant local bean variety on *kibanja* and 3 kg on *kikamba*. Average yields for Lyamungu 90 grown on *kibanja* were 658 kg/ha, with no significant difference by production zone. Average yields for local large-seeded bean varieties are estimated at 200 kg/ha to 969 kg/ha.

The area sown to Calima types on both *kibanja* and *kikamba* did not differ significantly for male- and female-headed households. On average, adopters in high-potential areas sowed a significantly larger area to Calima types on *kibanja* compared to adopters in less favourable zones (table 3). However, six of the 12 adopters who sowed more than 10% of total bean area on *kibanja* to Calima types in *vuli* 1997 lived in medium-potential areas. Among adopters who sowed Lyamungu 90 on *kikamba*, Calima mixtures covered over 15% of the total bean area.

Table 3. Area (ha) Sown to Calima Seed Types by Land-Use and Production Zone, *Vuli* 1997

	Overall sample (n=26)	High potential (n=7)	Medium potential (n=11)	Low potential (n=8)
<i>Kibanja</i>	0.06*	0.12	0.06	0.02
<i>Kikamba</i>	0.05	0.04	0.04	NA

*Difference between zones is significant at $p \leq .02$.

Despite its low adoption, farmers rated Lyamungu 90 favourably. Twenty-seven of the 33 adopters planned to increase the amount of Lyamungu 90 sown in future seasons. Four planned to sow the same amount, while two planned to sow less. Comparing Lyamungu 90 to Rushara, a large-seeded landrace sown by a third of adopters (n=10), most farmers gave the new variety a superior rating on yield (eight cases), marketability (seven cases) and resistance to weevils (eight cases). Fifteen of the 28 adopters who sowed Lyamungu 90 on *kibanja* fields in 1997 reported positive benefits: mainly, increased income (eight households) and improved food security (three households). The other positive benefit mentioned was reduced cooking time and fuelwood savings, an observation corroborated by a 1998 study that estimated that switching to Lyamungu 85/90 saves 10% of a household's annual fuelwood consumption (Nkonya et al., 1998).

Farmers reported no negative impact from growing Lyamungu 90. Six adopters stopped growing other bean varieties after adopting Lyamungu 90, mainly due to low marketability of the disfavoured variety, but it is unclear whether their behaviour was directly related to the uptake of the new variety.

Reflecting the general trend in Bukoba District,⁵ relatively few adopters sold beans. Only 10 out of 28 households had ever sold Lyamungu 90 grown on *kibanja*; half of them only once. Seven households sold Lyamungu 90 grown on *kibanja* in *vuli* 1996. Only three households had ever sold Lyamungu 90 harvested from *vikamba* fields and, in *vuli* 1996, only two households had sold that variety.

EXPLAINING THE LOW ADOPTION OF LYAMUNGU 90

Tanzanian researchers had great expectations for Lyamungu 90 in the Kagera Region, anticipating high adoption rates and uptake of the variety largely as a cash crop grown on *vikamba* fields. This study did not document these expectations in Bukoba District and instead showed low adoption rates for Calima types six years after the variety was introduced. Most farmers sowed Lyamungu 90 on *vibanja* fields for home consumption. Yet, our findings suggest that farmers regarded Lyamungu 90 favourably. Nearly half of the adopters sowed more than 10% of the bean area on *vibanja* fields to a mixture of Lyamungu 90 and Rosecoco, and Calimas types received high ratings when compared with a large-seeded landrace. Is the Bukoba case yet another example of farmers rejecting a modern variety? Results from this and other studies suggest two major reasons for the low adoption of Lyamungu 90 at the time of the study: the unavailability of seed and low market demand for a variety farmers perceived primarily as a cash crop.

Seed supply problems

Lyamungu 90 seed was distributed only once by researchers in the belief that ‘a good variety will sell itself’ and move quickly and efficiently from farmer to farmer. Indeed, over half of the adopters (59%) first obtained Lyamungu 90 seed from other farmers (figure 2). However, two observations suggest that access to seed was problematic and contributed to low adoption. First, survey findings show that some farmers had problems retaining Lyamungu 90 seed and either ate, sold, or lost it as a result of crop failure or storage problems (table 1). The literature on adoption of bean varieties provides ample evidence of the difficulties faced by small-scale bean farmers in retaining seed, especially of new varieties. Sperling and Loevinsohn

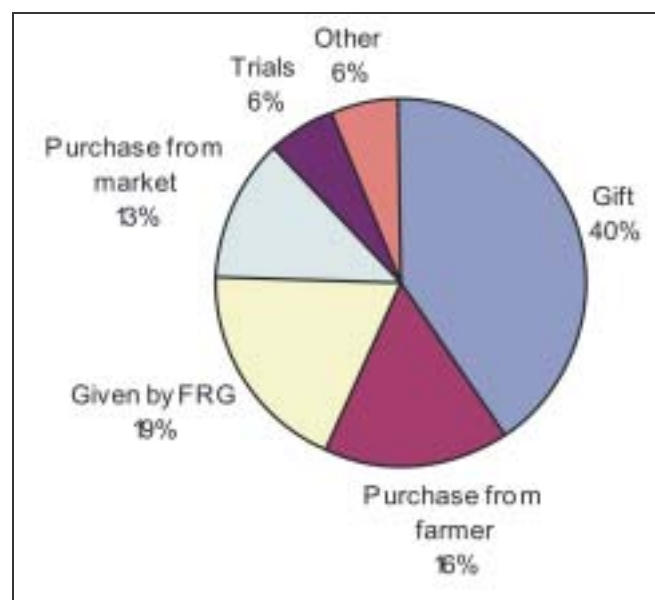


Figure 2. Initial source of Lyamungu 90 seed (n=32)

(1993) found that among Rwandan farmers who stopped growing an appreciated bean variety, the most common reasons were agro-environmental (drought, excessive rain, or storage and other pests) (36%), followed by varietal-specific (33%) and socio-economic (illness, lack of labour, consumed seed due to

⁵ Among 78 households surveyed across the district in 1993, 45% did not sell beans (Nkuba et al., 1995).

hunger) (30%) causes. Among farmers surveyed in the Lushoto District, Tanzania, who no longer grew Lyamungu 85, 77% had lost the seed during a drought (Ndakidemi and Mushi, per. comm.). The seed systems literature suggests that the amount of seed initially received, varietal productivity, the favourableness of the environment, and farmers' socio-economic characteristics are important determinants of farmers' ability to retain and diffuse seed (David and Sperling, 1999).

There is also evidence that the nature of seed networks and the dynamics of seed exchange among farmers in Bukoba may not necessarily facilitate the rapid adoption of introduced crop varieties. Higher adoption of Lyamungu 90 in participating villages suggests that in Bukoba, seed diffusion networks may be geographically and socially narrow. The 1994 follow-up survey of Lyamungu 90 seed recipients (Mafuru et al., 1996) also documented a lengthy time lag between when a farmer received Lyamungu 90 seed and when she shared it with others. Three years after the seed distribution exercise, 62% of seed recipients had not given seed to other farmers (Mafuru et al., 1996). One reason for slow diffusion of new varieties is that farmers require at least two to three seasons of experimentation before sharing new materials (Pachico and Ashby, 1983; Sperling and Loevinsohn, 1993).

The second evidence of a problem with seed access in Bukoba District is anecdotal reports of increased adoption rates after 1998 as a result of increased seed delivery efforts. Since the late 1990s, two development projects (the Bukoba District Rural Development Program and the Kagera Agricultural and Environmental Management Project) have been actively involved in distributing Lyamungu 90 throughout the district. Their activities include contracted seed multiplication, seed sales through stockists and agricultural stores, and more recently, the development of farmer seed enterprises. Anecdotal evidence, yet to be verified by a formal survey, suggests that in 2000, two years after the present survey, there was significant adoption of Lyamungu 90.

In a situation where seed supply was limited, researchers could have encouraged adoption by actively promoting Lyamungu 90. Promotional messages at the early stage of dissemination should have emphasised differences between Lyamungu 90 and existing Calima types, given the variety a local name to stress its difference from other Calima types, indicated the names of villages where seed was available, and encouraged farmers to retain seed in the absence of a seed supply programme. Promotion should have targeted traders as well as farmers.

Low market demand

Low market demand for Lyamungu 90 was an important deterrent to adoption. However, there is contradictory evidence on market demand for Calima types in Bukoba District. All traders interviewed by Mafuru and colleagues (1996) in 1994 ranked Rosecoco among their top 3 most preferred bean varieties. Seven out of 10 adopters rated Lyamungu 90 as 'more marketable' than Rushara. Yet, few adopters sold the variety, and a major reason why farmers intentionally stopped growing it was lack of market. Two explanations can be offered for low or fluctuating market demand for Lyamungu 90. First, market demand varies by type of trader, location, and point of sale. Mafuru and colleagues (1996) noted that traders in Bukoba Town central market ranked Rosecoco first, while it was ranked third (after Kisapuli and Rushara) by traders in rural markets. Since, the majority of farmers in Bukoba sell beans to traders from their homes to avoid transport costs and market levies (Nkuba et al., 1995), it is not surprising that most experienced difficulty in selling Calima types.

Second, low market demand may reflect the unwillingness of traders to purchase small quantities of a new seed type (i.e., Calima) available only from a few farmers. Low market demand was probably exacerbated by the approach to seed distribution used by researchers. Distributing seed of a new variety to a small number of farmers across several villages, in contrast to a cluster approach, prohibits the multiplier effect needed to encourage seed diffusion, adoption, and market demand. Further research is needed to estimate the critical mass needed to accelerate these processes. Survey and anecdotal evidence suggests that there is high market demand for Lyamungu 90 and other Calima types in neighbouring Karagwe District, where there has been significant adoption (Mafuru et al., 1996; D. Rukazambuka, per. comm.).

CONCLUSIONS

This paper proposes that two major factors accounted for the low adoption of Lyamungu 90 in Bukoba District in 1998: (1) limited seed distribution and promotion and (2) low and fluctuating market demand, which was partly caused by the strategy used for disseminating seed. This discussion does not, however, establish the relative importance of these two factors. Our results suggest that failure to consider seed availability as an adoption constraint might have led to the erroneous conclusion that farmers rejected

Lyamungu 90 solely on the merits of its characteristics and performance. As David and colleagues (1997: 292) correctly point out, ‘the adoption of a new bean cultivar is a complex and non-linear (i.e., not one-time) process’. Efforts by researchers and development workers to promote rapid adoption of new varieties of beans and other self-pollinating crops must therefore begin with a suitable seed dissemination strategy. The best system is one that re-supplies seed through multiple channels (i.e., commercial and non-commercial) over a number of seasons until the variety becomes fully established in local seed networks and markets. This can be achieved in the short term through specific seed distribution efforts, projects, and campaigns (e.g., efforts to promote new bean varieties in Malawi described by Chirwa and Aggarwal, 2000) or, more sustainably, by developing seed production capacity locally at the household or commercial level.

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SMALL-SCALE BEAN SEED PRODUCTION: ACHIEVEMENTS AND PROGRESS

Kibiby Jabir Mtenga

ABSTRACT

For many years, Tansed, a government seed organisation in Tanzania, made a deliberate attempt to produce, process, distribute, and market the seed of a wide range of crops to farmers. However, in the early 1990s, Tansed had to become more commercial, producing crops/quantities they could sell, and gradually dropped the production of crops such as wheat, paddy, cowpeas, beans, and greengrams, which are consumed mostly by small-scale farmers. Tanzania liberalised its seed multiplication and distribution systems in the early 1990s, and private commercial seed suppliers started to produce seed. However, these private suppliers concentrated only on high-value crops like hybrid maize and had little interest in the small-scale farming sector, where crop and variety diversity is important. Since 1995, some NGOs, public institutions, and farmers' associations have initiated local seed-supply schemes with the aim of improving the seed supply of appropriate crops and varieties to increase farmers' food security and income. The SUA-Bean Project initiated a bean-seed multiplication programme in 1998. This paper aims at sharing the achievements and progress of the SUA-Bean seed-production programme with other bean stakeholders with a view to improving farmers' food security and income.

RÉSUMÉ

Pendant de nombreuses années, Tansed, une organisation semencière gouvernementale de Tanzanie, a essayé délibérément de produire, traiter, diffuser et commercialiser les semences d'un large éventail de cultures destinées aux exploitants. Toutefois, au début des années 1990, Tansed, contrainte de devenir plus commerciale, a opté alors pour les produits/quantités les mieux adaptés à la vente et a progressivement abandonné des produits tels que le blé, le paddy, le dolique, le haricot et le soja vert qui sont essentiellement consommés par les petits exploitants. À cette même époque, la Tanzanie a libéralisé sa multiplication et ses systèmes de distribution semencière et des fournisseurs privés se sont lancés dans la production, en se concentrant toutefois sur des végétaux à fort rapport économique sans éprouver le besoin de s'intéresser au secteur des petites exploitations où la diversité des plantes cultivées et des variétés est importante. Depuis 1995, quelques ONG, des institutions publiques et des associations d'agriculteurs ont initié des projets locaux de fourniture de semences avec l'objectif d'améliorer l'approvisionnement en semences des plantes et des végétaux appropriés afin d'augmenter la sécurité alimentaire et les revenus des agriculteurs. Le projet de l'Université d'agriculture de Sokoine (SUA) sur le haricot a commencé en 1998 un programme de multiplication de semences.

INTRODUCTION

In Tanzania more than 80% of the population live in rural areas and depend on agriculture (Mwaisela, 2000). In addition, 90% of the seeds used in agriculture are those saved by farmers themselves, which have been recycled for many years, contributing to poor crop productivity, leading to food insecurity and low income levels.

Improved seed is the most important input in crop-production systems in determining yield potential (Cromwell, 1990; Maredia and Howard, 1998). Improved seed has the additional important characteristics of early maturity, disease, and drought resistance essential to increasing farmers' food security and income (Ministry of Agriculture and Co-operatives, 1997).

In Tanzania, Tansed (Tanzania Seed Company Limited) was established as a government parastatal in 1973, taking over seed production, processing, distribution, and marketing activities (Ministry of Agriculture and Co-operatives, 1997; Due 1988; Shuma and Minja, 2000). For many years, Tansed attempted to produce seed for a wide range of crops, to ensure their accessibility and availability to the farming

communities. However, in the early 1990s, when the government introduced trade liberalisation, Tansed had to become more commercial, producing crops and quantities they could sell, rather than considering what was really demanded by the farming communities. Crops such as hybrid maize, composite maize, sunflower, and wheat were produced in a greater proportion than grain legumes, thereby limiting the availability and accessibility of the majority of farmers to improved bean seed (Mtenga, 1999). As a public seed organisation, Tansed has failed to supply seed for appropriate crops to farmers.

Due to Tansed's failure, the government liberalised the seed industry in 1990, and private commercial seed companies were allowed to produce and distribute seed to farmers. These companies include Monsanto (Tanzania) Limited, East African Seeds Company, Kenya Seed Company, Alpha Seeds, Pop Vriend, Sluis Brothers, Rotian Seeds Ltd, Pannar (South Africa), Incofin, Pioneer, Incomet Ltd, Maungu Seeds Ltd, and Zenobia Seeds Ltd (Lumbadia et al., 2000). All these companies produce and distribute seed with a high profit margin, like flowers, vegetables, and hybrids, which farmers could not afford to purchase and produce themselves. This did not resolve the major constraint of producing low-profit seed necessary to farmers.

The bean cowpea Collaborative Research Support Programme (CRSP) in Tanzania has bred two bean varieties—SUA 90 and Rojo—but few seeds for these varieties have been multiplied for wider dissemination to farming communities. This was due to a failure of the public seed sector to produce the anticipated amount of seed to be distributed to farmers. The SUA Small-Scale Bean Seed Multiplication Programme was initiated in 1998 to improve the availability and accessibility of bean seed to farmers. Other initiatives are on the way through the Selian and Uyole research institutes and CIAT in different agro-ecological zones with different types of bean varieties.

METHODOLOGY

The SUA-Bean Project had two approaches for implementing small-scale production of bean seed:

1. studying two major community-based seed-production strategies initiated by the Lay Volunteer International Association (LVIA) and Christian Council of Tanzania (CCT). These were the only two seed-production programmes operating in 1999 when the bean seed study was conducted. The study aimed at identifying and learning the mechanisms used by LVIA and CCT for small-scale seed production and to select the best approach appropriate for small-scale bean-seed multiplication. The result was that the SUA bean-seed multiplication scheme was able to borrow some of the seed-production mechanisms from both LVIA's and CCT's community-based seed-supply strategies
2. training small-scale farmers (particularly women) in seed multiplication

SMALL-SCALE BEAN SEED MULTIPLICATION: WHAT HAS BEEN DONE

Small-scale bean-seed multiplication activities started in the 1998/1999 seasons. The project selected and trained 10 farmers in two villages (Msolwa and Kisanga) in the Kilosa District to produce and distribute bean seeds to farming communities. Farmers were selected by gender and education. Each farmer was provided with 15 kg of seed to plant on 0.5 acre and produces seed individually. However, the seed multiplied by these farmers is too small (40 kg to 80 kg) for any significant impact.

The project also initiated bean-seed multiplication in collaboration with an Italian NGO (LVIA) in the Kongwa District, Dodoma Region. Kongwa is a semi-arid area with drought conditions for as long as a year. The SUA-Bean CRSP provides support in training and providing bean seed, fertilisers, pesticides, and packaging materials to small-scale farmers in Kongwa, while LVIA provides technical support in supervising bean-seed multiplication and selecting small-scale seed producers. Farmers of medium economic status were selected to produce the bean seed. The project started with two farmers' groups in 1999 but expanded to include six more farmers' in 2000. Each farmers' group was provided with 30 kg to plant on 1 acre. Despite the drought conditions in the area, farmers were able to get up to 430 kg of bean seed per acre, where normal yield levels for traditional bean varieties are 20 kg to 40 kg per acre. With the increase in yields observed by farmers producing seed, more area (2 to 3 acres) was allocated for bean-seed multiplication in 2000/2001 for both pilot and new farmers.

Working with small-scale farmers has led the project to realise that the amount of seed produced is too low for wider dissemination and adoption of the bean CRSP varieties. Hence, commercially oriented farmers, secondary schools, teachers' colleges, and large farms were co-opted in 2001 to multiply bean seed in

lowland areas of the Tanga and Arusha regions. Each of these seed producers planted 2 acres of bean seed. Seed producers' fields were visited this past mid-May, and the plants' performance is good.

Achievements of SUA-Bean multiplication activities

- Bean-seed multiplication is in place in Morogoro, Dodoma, Arusha, and Tanga regions.
- Bean yields have increased by 80% using improved bean varieties.
- The income of seed producers has increased through selling the bean seed they produce.

Long-term achievements of the project

- Food security of farmers has improved through adoption of improved CRSP varieties.
- More farmers will be producing SUA-Bean varieties by 2003.
- Farmers' income increased through selling more SUA-Bean varieties.

CHALLENGES/CONSTRAINTS FOR SMALL-SCALE BEAN SEED MULTIPLICATION

- Because small-scale production activities are for subsistence, this category of farmers might not be a good target for successful bean-seed multiplication as an enterprise. In most cases, the bean seed produced is eaten or sold at a grain price to meet the farmer's household demands for medication, school fees, food, etc. Farmers might not be in a position to share seed-multiplication costs if they don't realise any profit from seed multiplication. Farmers who are financially capable of sharing costs in seed multiplication are likely to be successful seed producers.
- Changes are needed in the quality-control procedures for community-based seed production. The regulations and requirements for differentiating seed grades are not clear.
- The market for seed is still a major problem. Most bean-seed producers have failed to sell most of the seed produced. Promotion activities have been conducted in Kongwa District and also need to be conducted in other areas of bean-seed multiplication. More marketing strategies are needed, for instance, designing appropriate recipes for bean meals or increasing people's awareness of the role of beans in reducing cancer might be useful in creating market avenues for bean-seed producers.

CONCLUSIONS AND RECOMMENDATIONS

- Small-scale bean-seed multiplication schemes are viable and hold potential for improving the availability and accessibility of improved bean varieties.
- Appropriate selection of seed producers is very important for successful bean-seed multiplication. Farmers should be selected based on their financial ability to produce bean seed, especially when the project supporting them is phased out.
- There should be a clear marketing strategy on how farmers can market their seed. Most of the seed-production programmes face this problem.

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LA VULGARISATION DE LA TECHNOLOGIE SEMENCIÈRE DANS LE SUD-KIVU : EXPÉRIENCE DU SENASEM, DES ONGD ET DES FERMES SEMENCIÈRES

Jonathan Mazambi Byakombe

RÉSUMÉ

La mission du Service National de Semences (SENASEM) au Kivu est de vulgariser les techniques de multiplication de semences pour que celles-ci soient utilisées dans les coins les plus reculés de la province. En 1996 le SENASEM a lancé le « Programme semencier du Sud-Kivu », dans le but de développer la multiplication de semences améliorées par des groupements paysans encadrés par les organisations non gouvernementales de développement (ONGD) et des exploitants privés et publics. Le rôle principal du SENASEM est d'exercer un contrôle sur la production semencière, en surveillant aussi bien la qualité variétale obtenue dans les champs et en laboratoire, que les multiplicateurs et leurs activités. Il a ouvert ses propres champs de production de semences mères, les mini-fermes de semences primaires. Le SENASEM favorise la collaboration avec les multiplicateurs et il lui incombe de certifier la production semencière réalisée. Depuis 1996 la production semencière par les associations de multiplicateurs encadrés n'a cessé de croître, tant du point de vue des quantités de semences distribuées et multipliées que du point de vue des revenus des structures multiplicatrices. La production semencière du haricot augmente d'année en année.

ABSTRACT

The National Seed Service (SENASEM) fulfils an extension role in Kivu to ensure that seed-multiplication technology reaches the province's most remote corners. The « Programme semencier du Sud-Kivu » that SENASEM launched in 1996 is aimed at helping farmers who have formed farmer organisations and operate with ONG support and the assistance of public and private seed growers, to develop their seed-multiplication and dissemination capacity. SENASEM's main role is to supervise the country's seed-production activities: it controls varietal quality, on-farm as well as in laboratories, and it monitors the activities of seed operators, after selecting and training them. It has its own 'primary-seed mini-farms', where it produces basic seeds. SENASEM favours collaboration with seed operators and is responsible for the control and certification of all seeds produced. Seed production carried out by assisted seed operators has been on the increase since 1996, in terms of the quantities multiplied and disseminated as well as of the income generated by the seed-growing enterprises. The production of bean seeds is steadily increasing.

INTRODUCTION

L'une de causes majeures du sous-développement de la République Démocratique du Congo (RDC) et, en particulier, de la Province du Sud-Kivu, demeure la sous-production agricole et ses nombreux corollaires : la sous-alimentation, la malnutrition, la pauvreté etc. Dans le Sud-Kivu, cette situation découle d'un ensemble de facteurs.

Le premier facteur est la rareté de semences qui soient à la fois de bonne qualité et adaptées aux conditions locales. En effet la croissance de la production du secteur agricole repose en grande mesure sur l'introduction de telles semences puis sur le maintien de la pureté génétique de ces types de semence, d'où l'importance d'une production semencière réalisée au niveau provincial.

Un deuxième facteur essentiel est la distribution aux ménages agricoles, par des agences semencières, d'une semence impropre à l'usage semencier et entraînant ipso facto la chute de la production.

À cela s'ajoute encore la politique de la main tendue pratiquée par la plupart des Organisations non

gouvernementales (ONG) internationales de développement (ONGD/ONGI) et des organisations onusiennes, politique qui fait que les agriculteurs, au lieu d'amorcer l'exploitation de leurs propres champs semenciers, s'attendent fréquemment à voir arriver d'une saison à l'autre la manne de semences distribuées par ces donateurs. Il faudrait sensibiliser ces agriculteurs et les préparer à se prendre en charge dans ce domaine semencier, surtout dans les après-guerres, lorsque les situations d'urgence nécessitant l'aide humanitaire ont pris fin. Il est vrai que les conflits ethniques et les guerres nous ramènent toujours presque à la case départ : lorsque les personnels des ONGD et les multiplicateurs encadrés doivent fuir et quitter leurs projets et exploitations, ils perdent souvent tout ce qu'ils avaient investi. Nous sommes donc appelés à ne rien ménager pour assurer que nous soyons toujours en mesure de disposer des semences mères indispensables, d'une année à l'autre voire d'une saison à l'autre.

PRÉSENTATION DU SENASEM

Bref aperçu

Le Service national des semences (SENASEM) est l'un des services spécialisé du Ministère de l'Agriculture et du Développement Rural créé par l'arrêté départemental n° 003/BCE/AGRIDRAL/84 du 12/05/84. La mission du SENASEM, qui fut à l'époque le « BUNASEM » (Bureau National de Semences), est de satisfaire les besoins du pays en semences par la création d'une industrie semencière cohérente. Il est l'organe de conception, de coordination et de contrôle des activités semencières en RDC. En effet, l'un des préalables déterminant l'aboutissement de toute politique de la production agricole d'un pays est l'utilisation des semences de bonne qualité, des variétés les plus performantes.

Climat

Notre rayon d'action s'élargit sur l'ensemble de la Province du Sud-Kivu qui jouit de plusieurs types de climats. Le climat qui règne est celui tropical de montagne (CW). Ce climat caractérise la région du Bushi montagneux où nous travaillons suffisamment. Il est doux en raison de l'abaissement de la température avec l'altitude croissante, qui varie de 1 460 m (niveau du lac Kivu) jusqu'à plus de 3 000 m au sommet des hautes montagnes. Jusqu'à 2 000 m d'altitude, à quelques variantes près, les caractères climatiques demeurent comme suit :

- précipitation annuelle moyenne de 1200 à 1700 mm, augmentant de l'est à l'ouest.
- trois mois de saison sèche plus marquée.
- diminution régulière de la température avec l'altitude.

Signalons qu'en plus de ces deux régions climatiques, il y a la zone de moyenne altitude dans les parties situées entre les zones précitées.

Tableau 1. Les trois grandes zones agricoles du Sud-Kivu

Région	Altitude	Climat	Saison sèche	Précipitation
Basse	700 à 1 200 m	<ul style="list-style-type: none"> • Tropical semi-aride dans la Plaine de la Ruzizi • Tropical humide en région forestière 	4 mois	
Moyenne	1 200–1 600 m	Tropical de montagne (cw)	3 mois	1 200 à 1 700 mm
Haute	1 600–3 000 m ≈ 1 750 m	doux en raison de l'abaissement de la température avec l'altitude croissante	3 mois – sècheresse plus marquée	

Le personnel

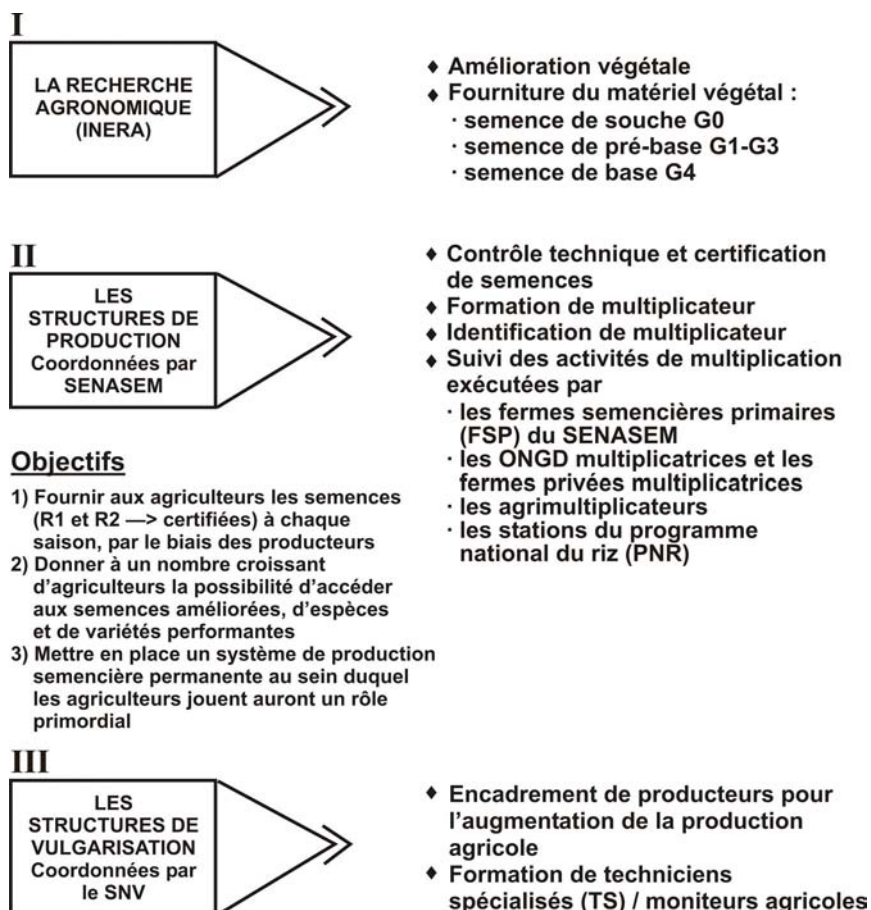
Lors de la création de la Coordination du SENASEM Sud-Kivu, en 1996, la Direction Nationale envisageait d'avoir un Coordonnateur épaulé d'un ou de deux techniciens, qui encadreraient un petit nombre d'agriculteurs multiplicateurs. Ce scénario a évolué avec le temps et suivant l'accroissement du nombre des encadrés.

L'effectif de la Coordination s'élève aujourd'hui à huit : un coordonnateur provincial, un chargé de la production, un secrétaire administratif et financier, un technicien de laboratoire provincial (TLP), deux

inspecteurs semenciers délégués (ISD), un huissier attaché au laboratoire et une réceptionniste, qui se charge aussi de l'entretien des bureaux.

Malgré cette augmentation, le besoin de personnel supplémentaire perdure, le bureau grandissant progressivement avec l'acquisition d'un équipement informatique et d'une partie d'équipement de laboratoire ; l'accroissement du nombre de partenaires et l'augmentation de superficies exploitées dans les mini-fermes semencières, etc.

Le schéma résumé de la filière semencière RDC



LES OBJECTIFS DU SENASEM

Après avoir constaté, dans la Province du Sud-Kivu, l'approvisionnement insuffisant en semences de base, le manque de cadres formés à la production et au contrôle de la qualité des semences, le prix très élevé des semences, l'absence durement ressentie de structures semencières en province et la dynamique des ONGD, le SENASEM a initié dès avril 1996 le « Programme semencier du Sud-Kivu », dans le but de développer la multiplication de semences améliorées par des groupements paysans encadrés par les ONGD et par des exploitants privés, publics et ecclésiastiques. La priorité est accordée aux ONGD parce que c'est sur ces organisations sociales en milieu rural que s'appuient souvent les activités des intervenants.

Le Programme est appelé à couvrir toute la province du Sud-Kivu et tient compte de la représentativité climatique et culturelle de grandes zones agricoles telles que présentées plus haut.

Comme signalé plus haut, le SENASEM, faisant partie d'autres services spécialisés de notre Ministère, est la seule institution de **contrôle** de la production semencière, opérant à plusieurs niveaux.

Contrôle de la pureté variétale au champ

À ce niveau de contrôle, le SENASEM entreprend d'abord de connaître l'origine de la semence mère : provient-elle de l'Institut national pour l'étude et la recherche agronomiques (INERA), d'une « mini-ferme semencière primaire » (M-FSP), du SENASEM ou du Programme national du riz (PNR) ? Le SENASEM surveille la façon dont le travail au champ est mené pendant toute la saison culturale en effectuant trois ou

quatre visites d'inspection par champ semencier. Il cherche à détecter les cas d'attaques de maladies transmissibles par la graine, activité qui nécessite également des visites sur le terrain pour contrôler tous les champs semenciers ouverts pendant la saison culturale.

Le contrôle de l'origine de la semence de base : les intervenants et les difficultés rencontrées

La semence utilisée par les multiplicateurs pour l'ensemencement de leurs champs semenciers provient souvent des trois sources suivantes :

- de l'INERA, au respect de la filière semencière en vigueur au pays présentée ci-haut. La semence était achetée pour le SENASEM Sud-Kivu par la Direction nationale à travers les Projets PNUD/FAO/ZAI.
- des FSP à la disposition du SENASEM dans les provinces, c'est-à-dire celles de toutes les provinces à l'exception de celles du Nord-Kivu et la nôtre. C'est toujours la Direction nationale qui achetait la semence pour notre Coordination.
- des multiplicateurs encadrés à qui nous conseillons de ne reconduire comme semences mères que les deux premières générations (F1 et F2) issues de la semence de base en provenance de l'INERA et distribuées à des fins de multiplication. Il leur est interdit d'utiliser la R3 pour la simple raison que la culture accusant souvent une certaine dégénérescence ne peut plus donner les semences de qualité.

Sans subvention étatique pendant toute cette période de guerres dites de libération, l'INERA, coupée de la Direction nationale, n'est plus en mesure de nous doter de cet intrant capital et comme le SENASEM ne dispose pas de FSP, une solution palliative devrait vite être trouvée pour que les multiplicateurs n'exploitent pas plus de deux générations issues de semences de base distribuées en 1996.

L'ouverture de mini-FSP par le SENASEM Sud-Kivu

Pour contourner la difficulté décrite au paragraphe précédent, le SENASEM entreprendra le projet d'ouverture de ses propres champs de production de semences mères en provenance de l'INERA, du PNR, du FPS et d'autres provinces (Lombo, Gandajika, Lusanga, Dingila, Mbeko-Shaba).

Grâce au Christian Aid (CA) et aux recettes d'autofinancement nous amorçons ce projet de multiplication dans les deux grandes zones agroécologiques de la province (région d'altitude et de basse altitude). Le PNR Sud-Kivu s'associera à nous pour la multiplication des semences des cultures adaptées à l'écologie chaude et l'INERA avec le peu de moyens qu'il pourra trouver se chargera de la multiplication des semences adaptées à l'écologie froide suite à sa localisation en haute altitude.

Les sites choisis pour la création des mini-fermes du SENASEM sont Luberizi et Katogogota (en basse altitude) et Mushweshwe et Kashusha (en haute altitude). Les superficies exploitées dans ces mini-fermes sont présentées au tableau 2 :

Tableau 2. Superficies exploitées par le SENASEM

Année	Saison B	Saison C	Saison A
1998	—	21 ha	7 ha
1999	5,5 ha	5,37 ha	14,26 ha
2000	15,2 ha	8,8 ha	21 ha

Contrôle des activités des multiplicateurs

Le SENASEM pour le Kivu est appelé à contrôler les exploitations semencières ouvertes chaque saison par les multiplicateurs à raison de deux à trois visites d'inspection par champ par saison. Pour pouvoir s'acquitter de cette tâche, il lui faut les moyens financiers pour indemniser les inspecteurs (per diems et frais de mission) et leur procurer le matériel requis (outils, pièces de rechange, carburants et lubrifiants) ; il faut aussi des conditions de paix pour que tous les territoires soient accessibles.

Le SENASEM œuvre actuellement dans les territoires de Kabare, Kalehe, Idjwi, Walungu, et Uvira (partiellement accessibles) ; il ne reviendra dans les autres champs (de Mwenga, Fizi et Shabunda) qu'en temps de paix.

Grâce au CA et aux fonds générés par nos différentes activités (vente de produits des champs et recettes de laboratoire), le SENASEM se maintient en cette période de troubles : il continue d'approvisionner les multiplicateurs en semences mères et à effectuer le suivi et évaluation des activités.

Contrôle de la qualité de semence produite au Labosem

Avant tout conditionnement et stockage des semences, il faut tester les semences en effectuant deux séries d'analyse dans le laboratoire de semences (« labosem ») : une analyse physique et une analyse sanitaire.

L'analyse physique en Labosem informe sur les caractéristiques physiques de la semence dont la pureté spécifique de la semence, le pouvoir germinatif, le poids de mille graines ou le calibrage, et le taux d'humidité. Au total, le Labosem Sud-Kivu, bien qu'il soit encore équipé partiellement CA, effectue annuellement les tests suivants (tableau 3) :

Tableau 3. Analyses physiques menées au Labosem

Année	Semences vivrières	Semences maraîchères
1998	55	24
1999	127	20
2000	126	17

Ces tests concernaient les récoltes de multiplicateurs et celles de différents fournisseurs de semences aux acheteurs les distribuant dans le cadre humanitaire aux sinistrés du Sud-Kivu.

L'analyse sanitaire sert à détecter les maladies éventuelles que la semence véhicule soit extérieurement, soit génétiquement. Au Kivu, l'équipement partiel du laboratoire de semences a d'abord fait obstacle à la réalisation d'analyses sanitaires conformément aux normes internationales exigées par l'ISTA (International Seed Testing Association). C'est pour cela que le CA nous enverra en voyage d'études au Rwanda et au Kenya pour que nous y visitions les laboratoires de semences afin de nous imprégner de ce qu'ils y réalisent : ainsi nous serons en mesure de préparer un projet d'équipement du Labosem Sud-Kivu. Ce projet qui fut financé par la même institution, à 19,4 %, nous a permis de remplacer notre ancien équipement jugé rudimentaire.

TYPES DE SEMENCES VIVRIÈRES CONCERNÉES PAR LA MULTIPLICATION

Les équipements et l'infrastructure de conservation des semences étant insuffisants pour le traitement de la plupart des semences qui se reproduisent végétativement, la multiplication sous l'encadrement et le contrôle du SENASEM Sud-Kivu se limite aux spéculations à multiplication générative, faciles à conserver. La liste de ces spéculations est présentée ci-dessous.

Céréales

- Variétés du maïs : Kasai I, Bambou, ZP 70, Imbo, S.M., Babungo, Tambo.
- Variétés de riz pluvial : Irat 112 et Irat 13 ; variétés de riz irrigué : Sipi, Bouake et Iron
- Variétés de sorgho : Mbogombogo et Budwakali (variétés locales dont la sélection en masse est à envisager).

Légumineuses

- Variétés de haricot nains : Kirundo, Maragi Soja (G2858), M'mafutala, M'sole, D6, AND 620, Lub 1, Ituri Matata.
- Variétés de haricots volubiles : VCB 81012, AND 10, ALIYA, KIEMBE (G2331_[R.G.S.1])
- Variétés de soja: Imperial, Oribi, TGX 88849C..., Sable, Ngando.
- Variétés d'arachide : Red beauty, JL 24, Mandingu

Racines et tubercules

Les semences de racines et de tubercules font l'objet des programmes spéciaux de l'INERA, qui s'occupe de la production des semences pour leur diffusion.

- Manioc « clone doux » : F100
- Manioc « clone amère » : Naiunde, Nakarasi, ...

- Pomme de terre :Crouza, Montsama, ...
- Patate douce : Elengi

Semences maraîchères

Les semences maraîchères sont exploitées à petite échelle, à l'exception de l'amarante que l'on a déjà réussi à multiplier sur de grandes superficies. Grâce à l'assistance du Comité international de la Croix-Rouge (CICR), le SENASEM a encadré la multiplication de semences de tomate et d'aubergine effectuée par des membres de l'Institut technique agricole et vétérinaire (ITAV) de Mushweshwe.

LA PHILOSOPHIE DE TRAVAIL DU SENASEM

La collaboration avec le SENASEM requiert de passer par les étapes suivantes : contact ; explication concernant la ligne de conduite ou les normes à respecter ; visite de prospection des sites ; ouverture du contrat et signature d'un protocole d'accord ; formation en technologie semencière ; octroi des semences et explication sur les normes de restitution (2 fois la quantité reçue pour les légumineuses et 4 fois pour les céréales) ; visites de suivi et d'inspection (3 à 4 fois par saison culturale ; échantillonnage en vue des tests d'analyse physique après production et restitution : 4 fois pour les céréales et 2 fois pour les légumineuses) ; certification ou non ; distribution libre de la semence aux membres des associations ou vente libre aux acheteurs par le multiplicateur.

RÉSULTATS OBTENUS

Capacité de diffusion

Depuis que le SENASEM s'est installé au Sud-Kivu en 1996, le nombre d'associations encadrées s'est élevé à 202. Cependant, suite à l'insécurité liée à la guerre, ce nombre est tombé : aujourd'hui 84 associations sont accessibles. Par territoire, le nombre de ces encadrés multiplicateurs se présente dans l'espace comme suit :

Tableau 4. Les associations multiplicatrices encadrées par le SENASEM au Sud-Kivu

N°	Territoire	Nombre d'ONG multiplicatrices	
		accessibles	non accessibles suite à l'insécurité
01	Idjwi	5	—
02	Kabare	26	11
03	Shabundu	—	25
04	Walungu	7	14
05	Mwenga	—	24
06	Uvira	31	—
07	Fizi	13	36
08	Kalehe	2	8
Total		84	118

Accroissement de la production semencière

La production semencière par les associations de multiplicateurs encadrées par le SENASEM ne cesse de croître pour certaines spéculations, vis-à-vis de la quantité de semences mères distribuées chaque année (tableau 5).

La quantité de la production semencière vendue est à la base de l'accroissement des revenus des structures multiplicatrices (tableau 6).

Tableau 5. Distribution des semences mères aux multiplicateurs de 1996 à 2000

Année	Haricot nain	Haricot volubile	Maïs	Soja	Arachide	Riz	Sorgho	Petit Pois
1996	851	285,5	640,5	702,0	470	286	—	—
1997	1 527	80,0	973,7	539,9	890	641	—	300
1998	4 159	1 180,0	695,5	845,0	307	469	—	—
1999	3 826	430,0	1 726,5	1 180,0	280	0	—	—
2000	2 202	1 890,0	608,5	233,0	1 500	1 200	191	—
Total	12 565	3 865,5	4 644,7	3 499,9	3 447	2 596	191	300

Tableau 6. Productions semencières réalisées de 1996 à 2000

Spéculation	1997	1997	1998	2000
Haricot	2 800,0	48 364,2	42 096	83 000
Arachide	3 898,2	2 697,6	1 680	7 000
Soja	5 941,6	8 842,0	19 936	7 000
Maïs	42 588,0	22 508,0	111 300	55 916
Riz	6 708,0	8 211,0	—	16 000
Sorgho	—	—	798	920

La qualité des semences produites par les paysans multiplicateurs

S'agissant de la qualité des semences produites par les paysans multiplicateurs, il faut souligner que certaines associations réussissent à obtenir un produit de bonne qualité. Il s'agit de paysans qui ont été formés en technologie semencière et dont les moyens financiers, plus ou moins suffisants, leur permettent de mener à bon port leurs activités de multiplication. Par contre, d'autres multiplicateurs dont le bon fonctionnement est entravé par une foule de contraintes, produisent des produits de qualité bien inférieure. Les produits réalisés par cette catégorie d'agri-multiplicateurs sont très souvent déclassés soit au niveau des champs par les inspecteurs semenciers du SENASEM, soit parce que les analyses du Labosem révèlent qu'ils sont impropres à l'usage semencier.

Eu égard aux analyses de laboratoire que nous effectuons fréquemment sur les échantillons des produits des multiplicateurs, nous reprenons au tableau 7 quelques résultats de tests de semences de haricot de multiplicateurs :

Tableau 7. Analyses de laboratoire sur les semences de haricots

Date de réception (2001)	Provenance	Variété	Poids du lot (kg)	N° d'analyse	Cat.	Analyse de laboratoire						
						P.S.	Pds 1000	Germination				
								N	A	D	F	M
21/02	Agrimulti	Mmafutala	13 000	020145	R2	99	223,25	92	6	0	0	2
21/02	Agrimulti	G2858	8 000	020146	R2	99	169,93	94	3	0	0	3
14/02	Agrimulti	AND10	4 225	020131	R1	99,3	412,75	89	0	1	8	2
22/02	Agrimulti	VCB81012	21 113	021050	R1	99,7	417,50	93	0	0	4	3
21/02	INERA	AND 620	3 000	020147	SB	99	337,00	90	7	0	1	2

LE COÛT DE PRODUCTION

Le coût de production varie selon le milieu et l'époque de culture. Au Sud-Kivu il est plus élevé en basse altitude (plaine de la Ruzizi) qu'en haute altitude.

Comme dans les exploitations paysannes, ce sont les membres mêmes des associations qui effectuent les travaux (voir le cas des associations et confessions religieuses), il nous est un peu difficile de relever le coût réel dépensé à l'hectare par les agri-multiplicateurs. Néanmoins, sur la base des résultats d'une étude menée par la Coordination auprès d'un groupe de multiplicateurs et dans une mini-ferme, nous sommes aboutis aux coûts

d'exploitation d'un hectare de culture de haricots nain de l'ordre de 436,93 dollars américains (USD) en milieu paysan et de 880 USD mini-ferme. (Les coûts encourus en milieu paysan sont encore à étudier davantage.)

Le tableau 8 présente les coûts détaillés des données en mini-ferme du SENASEM.

Tableau 8. Coûts détaillés des données en mini-fermes du SENASEM

Opération	m.o./ha	Coût culture/ha (USD)	
		Haricots nains	Haricots volubiles
Achat semences	1 ha/culture	90	90
Défrichage	50 HJ x 1 \$	50	50
Labour	100 HJ x 1 \$	100	100
Hersage	50 HJ x 1 \$	50	50
Semis	100 HJ x 1 \$	100	100
Sarclage	100 HJ x 1 \$	200	200
Fertilisant	4 sacs/ha x 35 \$	—	140
Tuteurs		—	50
Tuteurage		—	20
Récolte	100 HJ x 1 \$	100	100
Séchage et battage	30 HJ x 1 \$	30	30
Achat Sacs vides		14	20
Achat Cordes ficelles		4	4
Achat produit de protection et m.o. pour traitement		30	50
Supervision Capita	2HJ x 60 jrs x 1\$	120	—
Total (USD)		888	1 274

Abréviations : HJ : homme jour m.o : main d'œuvre USD : dollars américains

Si les coûts de production semblent être plus élevés en mini-fermes SENASEM que chez le paysan multiplicateur, c'est parce que le paysan n'utilise pas beaucoup d'intrants (engrais, pesticides, etc.) et qu'il peut faire appel à la main-d'œuvre familiale ou bien exploiter les membres de l'association. En mini-ferme on calcule le coût de la main d'œuvre à raison d'un dollar américain (USD) pour un homme-jour (HJ). Si l'on faisait une analyse économique du coût de revient de la production du paysan en valorisant financièrement les travaux exécutés par la famille ou les membres de l'association, le coût approcherait celui de la mini ferme.

La réduction et la stabilité des prix de semences

Comparativement à l'année 1996, période correspondant à l'installation de la Coordination du SENASEM au Sud-Kivu, on peut remarquer une réduction sensible du niveau de prix ainsi qu'une certaine stabilité. À titre illustratif le tableau 9 présente l'évolution des prix de semences au Sud-Kivu :

Tableau 9. Évolution des prix des semences au Sud-Kivu

Spéculation	Prix (USD)/kg		
	1997	2000	
		s. de base	s. certifiée
Haricot et soja	2	1,2	1,0
Arachide gousse	2	1,5	1,2
Riz	1,8	1,2	1,0
Maïs	1,2	1,0	0,8
Sorgho	1,5	1,2	1,2

La réduction de prix de semences que l'on observe pour toutes les spéculations est le fruit des efforts que nous ne cessons de consentir avec l'INSPAGRI en matière de fixation de prix en vue de jouer notre rôle en province qui consiste, entre autres, à favoriser l'utilisation de la bonne semences par l'agriculture.

L'amélioration des moyens de production (usage de tracteurs pour les travaux de labour) entraînera une réduction plus poussée encore des coûts de production et donc aussi une diminution des prix.

Nombre de multiplicateurs formés

Au total, le nombre des multiplicateurs déjà formés s'élève à 250 personnes dans les sept territoires localisés dans notre rayon d'action. En considérant en outre le groupe de multiplicateurs n'ayant jamais bénéficié d'une formation, on peut constater que le total des personnes formées aurait été plus élevé s'il n'y avait pas eu les deux guerres successives qui nous ont coupés, il y a 3 ans, de nos bailleurs de fonds localisés au niveau de la Direction nationale.

L'augmentation du patrimoine du SENASEM et la réhabilitation du bureau

Le SENASEM dispose d'un immeuble qui abrite son bureau et le Labosem réhabilité et équipé en matériels par le fonds d'autofinancement et de deux véhicules à deux roues (motos) dont un déclassé, d'une machine à écrire électrique et d'une photocopieuse acquise sur un financement du Projet PNUD-FAO-ZAI. Grâce au CA, la Coordination a pu acquérir également un ordinateur complet, des instruments de laboratoire (équipement incomplet) nécessaires à l'analyse physique des semences, et enfin, deux motos neuves et une d'occasion.

EXIGENCES D'UN SYSTÈME DE MULTIPLICATION DE SEMENCES À PETITE ECHELLE

Pour un observateur non averti qui compare le système de semences à petite échelle au système de multiplication de semences en fermes semencières, le premier semble être le plus exigeant. La liste des exigences inclue les aspects suivants : moyens logistiques et financiers ; les vulgarisateurs de la technologie semencière ; le transport des encadreurs (moto, carburant, per diem, pièces de rechange) et les moyens de communication nécessaires pour que le vulgarisateur sur terrain soit en communication permanente avec sa base (bureau) ; la formation des techniciens des structures multiplicatrices qui s'occupent de l'exécution des activités de multiplication sur terrain.

Or si vous comparez le coût relatif à ces exigences avec ce que coûte la multiplication de semences en ferme semencière (frais d'investissement, d'évacuation des semences vers les utilisateurs éparpillés à travers la Province, coûts opérationnels) vous comprendrez que le premier scénario est de loin plus intéressant. Sans oublier que le système de multiplication en ferme ne peut en aucun cas être opérationnel en période de troubles, telle celle que connaît le pays aujourd'hui.

PERSPECTIVES D'AVENIR

Face à la liste de toutes les actions à accomplir, le SENASEM envisage de commencer par celles qui lui permettront d'améliorer la qualité de son travail en province. Il cherche avant tout à

- être branché sur différents réseaux internationaux, et en contact avec notamment des institutions de recherche internationales telles que l'ISTA, le CIAT, l'ECABREN pour mieux connaître tous les programmes sur la multiplication des semences de cultures vivrières.
- augmenter son parc automobile de façon à ce que chaque technicien puisse se déplacer sans difficulté pour suivre de près les activités des agrimultiplicateurs et que la Coordination puisse assurer le transport d'intrants (semences, engrais, produits phytosanitaire et même, au besoin, les récoltes des multiplicateurs) sans causer d'ennuis à des tiers ni risquer de dégâts aux gens ni aux produits mêmes (piétinement des semences, etc.).

EXPERIENCES WITH THE SUPPLY OF BEAN SEED IN MALAWI

R. M. Chirwa and V. D. Aggarwal

ABSTRACT

*Strategies to make bean seed available to farmers in Malawi have been successfully implemented on a pilot scale by the Bean Improvement Program in Malawi. Farmers have shown considerable interest in purchasing seeds of newly released bean (*Phaseolus vulgaris* L.) varieties; however, this seed is not yet available to farmers on a large scale. The private seed sector in the country is not interested in bean seed production because of low profit margins. Beans are a self-pollinating crop, and once farmers have obtained initial seed stock, it can be recycled for some time. One strategy has looked at alternative systems of sustainable, informal seed production and dissemination. It builds on lessons learnt from previous experiences within Malawi and other African countries, including (a) informal seed multiplication, using smallholder farmers, (b) informal seed distribution channels, using grocery shops, rural traders, extension agents, health clinics, and NGOs, and (c) intensified variety promotion through publicity, using posters, leaflets, brochures, and radio messages. These activities are carried out in close collaboration with farmers, NGOs, extension agencies, village traders, and various other institutions.*

Keywords: Bean seeds, seed multiplication, seed dissemination, promotion strategies

RESUME

Au Malawi, le Programme d'amélioration du haricot a introduit à l'essai avec succès des stratégies destinées à mettre des semences de haricots à la disposition des cultivateurs. Cependant, alors que les cultivateurs semblaient très intéressés à acquérir les variétés nouvelles introduites, celles-ci ne s'avèrent pas encore livrables à grande échelle. Du fait des faibles marges de profit, le secteur semencier privé du pays n'est pas intéressé à les produire. Le haricot est un végétal à pollinisation directe et une fois que les cultivateurs ont obtenu un stock de semences initial, celui-ci peut être recyclé pendant un certain temps. Une stratégie tenant compte d'autres systèmes durables et informels de production et de diffusion de semences et s'appuyant sur les leçons apprises au Malawi et dans d'autres pays africains, prévoit notamment. These include: (a) une multiplication semencière informelle s'appuyant sur les petits exploitants; (b) un réseau informel de distribution des semences s'appuyant sur les épiceries, les négociants ruraux, les agents de vulgarisation, les cliniques et les ONG, et (c) une promotion intensifiée de la variété au moyen de la publicité, grâce à des affiches, des dépliants, des brochures et des messages radiophoniques. Ces activités sont réalisées en étroite collaboration avec des exploitants, des ONG, des bureaux de vulgarisation, des négociants villageois et diverses autres institutions.

Mots clés: semences de haricots, multiplication semencière, diffusion semencière, stratégies de promotion

INTRODUCTION

Produced by smallholder subsistence farmers, most of whom are women, beans are an important food crop as a source of protein as well as income for many Malawians. It is a crop grown throughout Malawi, but commonly during the rainy season (with mean annual rainfall ranging from 800 to 1500 mm) in areas between 1000 and 1700 metres above sea level. Farmers grow beans under several cropping systems: pure stand; mixed stand with other crops, usually maize; relay crop after maize; in *dimba* gardens on residual moisture; under irrigation after rice in rice schemes; and in alleys of tree crops.

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Total bean production in Malawi is low, with a national average of only 27,500 metric tonnes in 1989, increasing to 60,500 metric tonnes in 1998. The total land area grown to beans has expanded from 93,500 ha in 1989 to 170,000 ha in 1998; however, yield per unit land area has changed only slightly: from 294 kg/ha in 1989 to an estimated 436 kg/ha in 2000. Bean yields under farmers' conditions are far lower than those realised under well-managed research conditions (which are in excess of 1500 kg/ha). Many factors—biotic, abiotic and socio-economic—significantly constrain bean production on smallholder farms in Malawi.

The main biotic constraints are diseases (angular leaf spot, common bacterial blight, halo blight, anthracnose, and common bean mosaic virus) and insect pests (bean stem maggot, aphids, ootheca beetle, and bruchids) (Wortmann et al., 1998). Abiotic constraints include low soil fertility and water stress, whereas the most important socio-economic constraints are lack of seeds of improved varieties, poor pricing policies, lack of affordable farm inputs, and poor storage facilities (Mkandawire, 1992).

TECHNOLOGY DEVELOPMENT

Since beans are important in the diet of Malawians, there have been considerable research efforts to develop improved technologies for bean production. Bunda College of Agriculture released six bean varieties in 1980. Out of these, four (Nasaka, Sapelekedwa, Bwenzilawana, and Kamtsilo) were dwarf types and two (Namajengo and Kanzama) were climbers. Breeders' seed of these varieties was provided to the National Seed Company of Malawi (NSCM) for further multiplication and distribution, but the company's interest in self-pollinated crops had declined because farmers were able to recycle the seed from their previous crop for a few years before renewing their seed stocks. As a result, not much seed of these new varieties was produced, and many farmers did not have access to these improved varieties.

In 1993, Bunda released three other bean varieties: Bunda 93 (a local accession), Chimbamba (derived from a cross between two local accessions), and Kalima (an introduced line, PVA 692). Not long after, in 1995, the DFID-funded Bean Improvement Project (BIP) at Chitedze Agricultural Research Station released an additional six new bean varieties: Napilira (CAL 143), Maluwa (CAL 113), Nagaga (A 197), Sapatsika (DRK 57), Mkhalaria (A 344), and Kambidzi (A 286), (Chirwa et al., 1997). These varieties represent two gene pools: the first four were of the Andean type, that are large seeded, and the last two are of Mesoamerican origin and are small seeded. All of them originated from CIAT in Colombia.

STRATEGIES FOR SEED MULTIPLICATION

The BIP had developed strategies and mechanisms to support and accelerate the transfer of new bean varieties to farmers in a sustainable manner (see Chirwa and Aggarwal, 2000, for an outline of these strategies). The work reported here is a follow-up of these strategies.

Primary (breeder and basic) seed production

Breeder seed multiplication

The BIP had a target of producing breeder seeds for their six new bean varieties each year. Breeder seed was produced either at research station farms or through contract farmers under direct supervision of BIP breeders to ensure variety purity. For example, in the year 2000, 7700 kg of breeder seed was produced by six contract farmers. Part of the breeder seed is stored to maintain a minimum stock of breeder seed, and the rest is used in subsequent seed-multiplication activities.

Basic seed multiplication

Further seed multiplication, to produce basic seed was done through collaborators—both large- and small-scale farmers. These farmers had direct contract with the BIP, in the same manner the farmers multiplying breeder seed did. The contracts clearly detailed that the BIP would buy back the seed from farmers at grain market price plus a 10% premium. The system had been operating successfully since 1996 and all contracted seed growers sold their seed to BIP. The quantities of seed realised for all varieties were 18 tonnes (1996), 40 tonnes (1997), 25 tonnes (1998), 50 tonnes (1999), and 95 tonnes (2000).

Secondary (commercial or non-commercial) seed multiplication

Although the system described above worked well with the BIP funding, the quantities of seed produced were far too small to meet national requirements, which were projected at over 2000 tonnes in 1999 alone. Therefore, there was a need to put in a sustainable mechanism to supply large quantities of seed. It was

envisaged that the ultimate success of the seed system would depend on secondary seed multipliers who worked closely with farmers or had easy access to farmers. Such mechanisms already existed in Malawi, both at the government level through the Action Group II of the Maize Productivity Task Force and at the non-government level through various NGOs. The involvement of both government and non-government institutions in seed multiplication was important for a steady and sustainable seed supply. The BIP had already initiated activities of bean seed multiplication with partners at both levels, as described below.

Collaboration with government organisations

Action Group II of the Maize Productivity Task Force was within the Ministry of Agriculture and Livestock Development and focused on assisting small-scale framers who were interested in seed production and marketing as a business. These rural communities had formed associations, and some of them were interested in beans. The BIP strategy was to work closely with Action Group II of the Maize Productivity Task Force, in particular to support those farmers in the associations who were willing to take up secondary bean seed multiplication as a business in the major bean-production areas. The BIP provides backstopping by supplying breeders' seed, basic seed, and technical support. During the 1998–99 cropping season, the BIP supplied over 10 tonnes of basic seed to Action Group II for both large-scale contract farmers and small-scale farmers in seed association groups.

Collaboration with non-governmental organisations

Various NGOs, such as, Action Aid, Christian Services Committee, Concern Universal, Self-Help Development International, Veza International, INTERAID, CPAR, Plan International, World Vision International, and Primary Health Care have participated in seed production and distribution in Malawi. The BIP's strategy was to work jointly with NGOs by supplying them with basic seed of improved bean varieties that they could use for their seed programmes to produce certified seed for subsequent distribution to other beneficiaries (small-scale farmers) and to produce lower grade seed (approved seed) for distribution to more farmers under the food-security programmes. During the 1998–99 cropping season, more than 17 tonnes were supplied to NGOs; in the 2000–01 season, the seed supplied to NGOs had gone up to over 30 tonnes.

Experiences in seed dissemination

The BIP had experimented with a number of alternative methods for bean seed provision. Apart from the seed that was sold to NGOs for their own local-level seed projects, the BIP also used some of this seed in small-packs, which were sold through various outlets such as grocery shops, schools, clinics, maize mills, extension agents, and NGOs. The 1998–99 season was the third year in which the BIP organised the production and sale of small-seed packs of the six new bean varieties. Table 1 shows the quantities of seed managed and sold by small shops over the past three years (1996–99).

Table 1. Seed Sales of Small-Packs by Merchants

Variety	Quantity of seed (kg)		
	1996/97	1997/98	1998/99
Kambidzi	163	1,772	334
Maluwa	129	2,157	581
Mkhalira	290	2,330	617
Nagaga	295	639	737
Napilira	210	3,343	659
Sapatsika	0	1,777	523
Total	1,088	11,009	3,451

Source: BIP annual reports 1996–97, 1997–98, and 1998–99.

The small-packs were available in three sizes: 100 g, 250 g, and 500 g. The seed was packed in small polythene bags that contained a simple printed label with the name of the bean variety. The BIP arranged with various outlets to market the seed in the major bean-production areas. The small-packs were delivered to the shop and a retail price was predetermined by the BIP and the merchant, with the merchant keeping 20% of the sale price. The merchants decided the types of varieties to stock and the quantities they could handle based on their knowledge of their customers. At the end of the season, proceeds from the sales and

the unsold seed were collected and returned to the research station. The remnant seed was evaluated for germination quality and re-offered on the market in the subsequent season if the quality was up to standard.

The BIP used several promotion strategies for the new varieties. Among the print media, were posters (A3-size), leaflets (A4-size), and brochures on a folded A4 page. The posters had colour photos of all six varieties and their names. The leaflets had a colour photo of one variety and described its basic characteristics. Both the posters and leaflets were in two local languages: Chichewa and Chitumbuka. In addition there was a brochure in English, which contained more detailed information on the varieties, their adaptation to specific agro-ecological zones, and recommended cultural practices for production, as well as post-harvest handling and storage information.

Mass media were also used, mainly radio advertisements and programmes. The commercial advert with jingles described the new varieties and their attributes, along with outlets where farmers could acquire the small-packs. These were aired three times a day for four weeks, just before planting. The programme was part of the on-going agricultural extension activity run through the Ministry of Agriculture, where farmers are provided all kinds of improved agricultural production technologies on all crops and livestock. These programmes run throughout the year and feature different technologies, depending on the time of the year.

Costs of small-packs

One of the principal challenges for a sustainable seed system was to produce and deliver seed at a reasonable cost. For sustainability, although the BIP financed the process, it wanted to recover as much of the costs as possible. In addition, the BIP wanted to be able to demonstrate that it was commercially feasible to produce and sell small-packs of seed for new varieties.

Attempts were made to calculate the real costs of producing and distributing the seed. Table 2 (developed using BIP records and estimates of other costs) shows data on the current costs at the time of calculation and the estimate of the unsubsidised cost of the small-packs.

Table 2. Estimated Costs of Small-Pack of Bean Seeds

Item	MK*/ton of seed
<i>Cost of seed (47.0%)</i>	
Direct payment to farmers for seed	28,600
Interest on loans of chemicals, foundation seed	472
Organising and contracting	81
<i>Conditioning and storage (13.5%)</i>	
Bagging and transport to research station	895
Labour, chemicals, polythene bags, labels	645
Interest charges	6,864
<i>Quality control (0.2%)</i>	
Seed 'certification'	117
Seed testing	6
<i>Delivery to shops (11.1%)</i>	6,900
<i>Promotion (0.9%)</i>	557
<i>Unsold stocks and losses (7.3%)</i>	4,514
<i>Merchant's margin (20%)</i>	12,413
Unsubsidised Selling Price (100%)	62,064

* MK26 = US\$1.00 (exchange as of July 1998).

The figures in table 2 indicate that in order for the BIP to recover all the costs of the small-packs, it would have to charge a retail price of about MK62/kg. The actual retail price in 1998 was MK40/kg. Bean prices (at harvest time) were about MK25/kg, although they rose at the time of planting. The bean packs were thus sold at a price that was not sufficient to recover all the costs. But this pricing strategy seemed a reasonable way of

introducing small seed packs to merchants and farmers. Furthermore, the real costs of bean seed delivered in this way appear to be about two and a half times the price of grain, which was well within the range of prices expected for commercial seed production for a crop such as beans. It would be most unlikely that seed could be delivered for less than twice the price of grain.

However, the detailed cost estimates given in table 2 can be used to look for ways of reducing costs. Can the Malawi operation (or other similar programmes) cut the costs? BIP's seed multiplication operation was and continues to be admirably efficient. It uses farmers in a concentrated area whose resources allow them a good chance of producing an acceptable yield. The premium paid to the growers is reasonable. The operation is able to take advantage of collaboration from extension agents to manage much of the supervision. Other programs might not be so fortunate, and supervision may involve additional costs.

The cost of delivering the seed is relatively high, but it is not reasonable to expect that this could be lowered. This is one of the costs that will likely be higher than what is expected in a conventional commercial seed operation. The purpose of the small-pack strategy, after all, is to deliver relatively small quantities of seed to dispersed and isolated communities.

Some savings, however, might be realised by lowering the amount of unsold seed. This could be accomplished partly by establishing a policy of 'no return' from the merchants. But care must be taken to maintain sufficient merchant interest in the programme. The merchants' margin could also be lower than their current 20% (MK8/kg). Merchants might accept an absolute margin on seed that was sold at a higher retail price.

Follow-up study on small-packs

Sale price of small-packs

In a follow-up study, both merchants and farmers were asked about acceptable prices for seed in small-packs. Merchants were asked if farmers would be willing to buy bean seed if it was priced at two, three, or four times the grain price. Similarly, farmers were asked about their willingness to buy small-packs at these price ratios (table 3).

Table 3. Seed Price and Willingness to Buy Small-Packs

Ratio of seed price to grain price	Proportion of farmers willing to buy	
	Farmers (N=150)	Merchants (N=13)
1:1	96%	92%
2:1	69%	62%
3:1	43%	23%
4:1	35%	0%

The merchants and farmers were in close agreement when the seed price was twice the grain price—both estimated that about two-thirds of farmers would be willing to buy the small-packs at that price. The merchants, however, were more cautious than the farmers as the price rose. In the opinion of farmers, there would be significant interest even if the seed price were three or four times the grain price. It was interesting to note that there was no difference in these estimates between farmers who had experience with small-packs and those who had never purchased them.

Merchants' experience with the sale of bean seed packs

A study was conducted in Rumph District, Northern Region, which was the major concentration of seed sales. Owners of 11 grocery shops and two input shops with experience selling small-packs were interviewed.

Five of the 11 merchants in the sample sold other types of seed (mostly hybrid maize), four sold pesticides, and two sold fertiliser. Only four of the shops had been in business since at least 1990; most had opened in the past two or three years.

When asked about the customers who purchased the small-packs, the merchants observed that slightly more than half of their customers knew the small-packs were available at the shop before they entered. They believed that the posters and the efforts of the extension service were the two major factors that helped farmers learn about the seed. Roughly half of the farmers knew the name of the variety they wished to buy, and they believed

this was largely because of extension messages. The merchants estimated that about a third of the small-pack purchasers were women. The most common questions the farmers asked were about the seed's agronomic characteristics (yield and disease resistance). Some farmers also asked about cooking qualities and growth habit. Only three of the merchants recalled farmers asking about seed quality (i.e., germination).

All the merchants expressed an interest in continuing the sale of small-packs. All but one expressed interest in the possibility of selling small-packs of other crops. The greatest amount of interest was shown for maize and groundnut seed. Most of the merchants (69%) said that they would be willing to pay for the small-packs at the beginning of the season rather than waiting until BIP staff returned to the shop at the end of the season. This could simplify the administration of the small-pack program (especially if a 'no return' policy could be implemented). It would also be an additional step in moving small packs toward commercial viability.

The majority of the merchants believed that the current retail price of the seed packs was acceptable, but three (23%) said the price was too high. Some merchants suggested that the price could be lowered to make the packs accessible to more farmers. On the other hand, a few farmers complained that they had paid above the suggested retail price for their seed packs, but this could not be confirmed. Most of the merchants in the sample sold all of their stocks in 1998–99. In some cases (such as at Ntchenachena), where many farmers plant beans in March or April, the small-packs had all been sold by January and many farmers were unable to obtain them. A number of merchants suggested that more emphasis should be placed on the smaller sizes, especially 100 g, so that farmers with little cash could at least afford to test the new varieties.

Both the campaign of radio announcements and the posters received the merchants' full support. They were particularly appreciative of the posters, which were useful for drawing customers' attention to the seed packs. In some instances, merchants gave copies of the leaflets to their customers, and they would like to do so more often. This was an indication of farmers' demand for simple printed information about varieties. More attention might be given to a wider distribution of small pamphlets that describe all the varieties that are available.

Farmers' experience with purchase of small-packs

A farmer survey was conducted in Rumphi District in early 1999. Because many of the merchants maintain records of their customers, it was possible to direct the survey towards farmers who had purchased the seed packs. The merchants' lists of seed buyers were used as a frame from which to select a random sample. The goal was to interview 100 farmers who had purchased small-packs. Because there seemed to be a high concentration of buyers in the Mpompha area, 40 buyers were selected from there and 20 farmers each from Mhaju, Ntchenachena, and Bolero. Selection was assisted by the extension agents and merchants who had been involved in the seed programme.

The area in which the seed sales were concentrated is relatively prosperous—close to trading centres, with access to better facilities than the average for Malawi. The average level of education of farmers in the area is also quite high. Of the 150 households interviewed, 19 (13%) were female-headed. About half of the households interviewed had at least 10 years of experience with bean growing, but a significant minority (31%) had been growing beans for three years or less. In about half of the male-headed households, the respondent said that both husband and wife participated in choosing which bean varieties would be planted, while in 28% of the cases, they said that the woman chose the bean varieties.

A total of 50 farmers who had not purchased bean seed were also interviewed. As with the buyers' sample, relatively more farmers were chosen from Mpompha. About one-quarter of the supposed 'non-purchasers' also turned out to have purchased some small bean seed packs in the past. Some farmers had first bought small-packs before 1998, vended through a collaborating NGO (Livingstonia Synod Primary Health Care Unit), which sold bean seed in small-packs to farmers in this area for a couple of years before the study, so many farmers already knew the characteristics of the new bean varieties.

CONCLUSIONS AND COMMENTS

The strategy of producing and selling small seed packs of new bean varieties in Malawi has been quite successful. In areas where the packs were available, many farmers purchased the seed, and the majority were satisfied with the new varieties that they acquired and were interested in purchasing other small seed packs. The merchants who participated in the scheme were enthusiastic and wished to continue to sell the packs.

Part of the success of the programme was due to a well-organised promotion campaign. Extension agents helped inform farmers about the availability of the small-packs and, in some cases, sold the packs at their offices. Announcements on the radio also helped raise awareness. Perhaps the most effective element in the

promotion campaign were the widely distributed colour posters that described the new varieties. Merchants spoke very positively of these posters and wanted to have additional material of a similar nature.

Farmers' limited awareness of new crop varieties was one of the principal problems limiting variety diffusion. The interest in the posters pointed to the possibility of producing additional descriptive material that could be distributed directly to farmers for their reference.

Even if widespread commercial uptake of the small-pack strategy is not immediately feasible, small-packs can be used in the interface between agricultural research and NGO or donor seed projects. There are many projects that either distribute seed to client farmers or try to organise local-level seed multiplication. There is often no standard procedure for these projects to acquire the seed that they use. It would be useful for such projects to become accustomed to buying small-packs (or, where appropriate, larger bags) of seed for their activities. This would help to organise and rationalise what is often a last-minute rush for seed. It would also establish the tradition of paying a fair price for seed and would help build the critical mass of seed demand that is required for a more sustainable seed system.

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SESSION 7
SYSTEMS MANAGEMENT AND SOIL FERTILITY

VERIFICATION OF RECOMMENDED RATES OF INORGANIC FERTILISERS IN MAIZE-BEAN INTERCROPPING UNDER CONTRASTING SOIL TYPES IN WEST KENYA

G. O. Rachier, B. Salasya, and C. S. Wortmann

ABSTRACT

Vihiga is a District in west Kenya with high agricultural potential, characterised by a large population, land pressure, and small-scale, resource-poor farmers. A maize-based cropping system predominates, with maize and beans as the major food crops. The production of these crops is on the decline because of low soil fertility - the main factor constraining food production in the area. Farmers apply limited amounts of inorganic fertiliser to the maize mono-crop and the maize-bean intercrop in the same hill at planting. No inorganic fertiliser is applied to the beans planted between maize rows. Farmers do, however, apply farmyard manure (FYM) to all the plantings, including the beans between the maize rows. The current recommended rates for both inorganic fertilisers and FYM are the same for the whole district, without diverse soil and climatic conditions taken into account. Furthermore, the rates are recommendations based on maize as the sole crop. Trials were conducted for two seasons to verify past results obtained from recommended inorganic fertiliser rates in contrasting soil types within the district, using maize and beans as test crops. The paper discusses the results obtained and points out difficulties in carrying out trials on maize-bean intercropping.

RÉSUMÉ

Vihiga est une région située à l'ouest du Kenya, à large vocation agricole, caractérisée par une forte densité démographique, un nombre de terres insuffisant et de petits exploitants pauvres. Un système de culture basé sur le maïs y prédomine, avec le maïs et le haricot comme principales cultures vivrières. La production de ces dernières est en déclin du fait de la faible fertilité des sols – facteur principal limitant la production vivrière dans la région. Les agriculteurs épandent des quantités limitées de fertilisants minéraux sur les semis de maïs en monoculture en culture associée avec le haricot. Aucun fertilisant minéral n'est épandé sur les haricots plantés entre les rangées de maïs. Toutefois, les agriculteurs épandent du fumier de ferme sur tous les semis, y compris les haricots intercalés entre les rangées de maïs. Les taux recommandés actuellement aussi bien pour les fertilisants minéraux que pour le fumier de ferme sont les mêmes pour l'ensemble de la région, ne tenant pas compte de la diversité des sols et des conditions climatiques. De plus, les taux recommandés sont basés sur le maïs en tant que monoculture. Des essais ont été effectués au cours de deux saisons afin de vérifier les résultats obtenus par le passé à partir des taux de fertilisants minéraux et de fumier recommandés sur des types de sols différents de la région en prenant le maïs et le haricot en tant que cultures-tests. Le document examine les résultats obtenus et souligne les difficultés de réaliser des essais sur la culture associée de maïs et de haricots.

Key words: *Fertiliser recommendation, maize-bean intercrop, verification trials, zone specific packages*

INTRODUCTION

Vihiga District in western Kenya is an area of high agricultural potential (Jaetzold and Schmidt, 1982). Lying between longitude 34° 30'E and 35° 0'E and latitude 0° and 0° 15'N, the district covers a total area of 541 km². It is one of the most densely populated areas in Kenya—approximately 1000 people per km²—with a total population of 690,411 and a growth rate of 3% (1999 census). There are 95,799 households with an average of six persons per household and an average farm size of 0.6 ha. The district falls within an altitude of between 1300 and 1500 meters above sea level. Approximately 90% of the area falls in the Upper

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Midland 1 (UM₁) agro-ecological zone, referred to as the coffee-tea zone, while about 10% is in the Lower Midland 1 (LM₁) agro-ecological zone (which is relatively lower in agricultural potential).

Rainfall is bi-modal, with a long rainy season between February and June. The short rains, usually accompanied by hailstorms, fall between August and November. The two seasons are however, not distinct as they often overlap. The area has a favourable climate, receiving about 1800 mm of rain per annum, well distributed throughout the year with about 80% reliability (Jaetzold and Schmidt, 1982). Rainfall is therefore not a limiting factor in agricultural production. Temperatures range between 20°C and 28°C, with minimum diurnal variations. The soils are related to the underlying rocks. Granite has given rise to light-brown, sandy-loams, which are susceptible to soil erosion. These soils have a humic top layer with an average pH of about 6. About 90% of the soils have low inherent fertility due to heavy leaching and poor management (Odendo, 1995; Ojiem, 1998).

Agriculture is the major economic activity in the district, and supports approximately 80% of the population, with the remaining 20% provided for by other activities such as commerce, trade, and some industries. Results of a study by Ojeim (1998) ranking farmers by wealth indicated that only 1.4% of the farmers can be considered wealthy, 30% are in the medium rank, and 66% can be classified as resource poor.

Agriculture in the district includes small-scale, subsistence-oriented farming using some low-level technologies. Crops include maize and beans (the major food crops), tea, cowpeas, sweet potatoes, eucalyptus, bananas, and some horticultural crops. Maize and beans are mostly intercropped, with maize planted in rows and beans planted in the same row as maize. Sometimes beans are planted in rows between the maize or sown at random in the maize rows (Nderitu, 1995). Production is on the decline due to low soil fertility, which is ranked first among the factors constraining food production (Ojiem, et al., 1996). This is a result of high rainfall, continuous cropping with few nutrients replaced or appropriate replenishment measures (Odendo, 1995; Ojiem, 1998). For example, farmers apply limited amounts of inorganic fertilisers to the maize mono-crop and to maize-bean intercrops in the same row or hill at planting. In this case, beans benefit directly from the fertiliser application. No inorganic fertiliser is applied to the bean crop between maize rows but beans benefit indirectly from applications on maize. In 1997, the average yields of maize were estimated to be 13 t/ha and for beans, 0.5 t/ha.

Recommendation rates for inorganic fertilisers and organic manures in maize and bean crops for Vihiga District are conflicting. These include 60 kg N + 60 kg P₂O₅ per hectare (Bhuong et al., 1989), while recommendations from the Ministry of Agriculture's Fertiliser Use Recommendation Project (FURP) indicate that application of N is not economical and only maintenance amounts of N are recommended (Onyango, 1994).

These rates are for the whole district and do not take into account the diverse soil conditions that exist within the district, and are based on maize as a sole crop. In addition, the recommended rate for inorganic fertiliser for maize of 60 kg N + 60 kg P₂O₅ per hectare is beyond the reach of the resource-poor farmer because of their high cost (Ojiem, 1994). The FURP results for western Kenya, including Vihiga, showed that actual fertiliser levels are lower than the agronomic recommendations because of inadequate cash and high fertiliser prices, compared to the price of maize produced (Onyango, 1994).

Demand for food crops in the district—particularly for maize and beans—is increasing because of rapid population growth. This demand must be met by enhanced production per unit of land, which can be done by using improved soil management practices, among other things (Mwania, 1997). The high cost of inorganic fertiliser calls for appropriate fertiliser recommendations and efficient use (Onyango, 1994).

OBJECTIVES

- 1 to verify fertiliser use recommendations for different soil types in the district
- 2 to fine-tune or adjust fertiliser use recommendations based on results obtained
- 3 to generate information towards the development of a decision guide for farmers on the use of inorganic fertilisers in maize-bean production systems
- 4 to establish site-specific, economic fertiliser recommendations for different soil types in Vihiga District

METHODOLOGY

On-farm fertiliser verification trials were carried out at two sites in Vihiga District in western Kenya during two seasons (the long and short rains of 1999 and 2000). Two sites, Lusiola and Ebwali, were selected on the basis of soil types and differences in the terrain. Six fertiliser rates were used as treatments, with maize and beans as test crops. The treatments were chosen to include the range of treatments used by FURP in Vihiga during the past trials. Farmers willing to participate in the trials by offering land and labour were selected jointly by researchers and local extension officers. Land preparation was done by farmers before the onset of the rains.

The trials were laid out in a randomised complete-block design in plot sizes of 3.75 x 3.0 metres. Each farmer served as a replication due to land limitations within the farms. Planting was done at the onset of the rains. Hybrid maize variety H 625, spaced at 75 cm, and improved bean variety KK 8 (tolerant to the local bean root rot) were used. A single row of beans was planted between the two rows of maize. Planting was done on the same day. Triple super phosphate (TSP) fertiliser 46% and calcium ammonium nitrate (CAN 27%) were used as sources of P and N, respectively. TSP was applied in the planting hole and mixed with soil before seed placement.

Three maize and two bean seeds were planted per hole and later thinned to one at first weeding. CAN was applied in two split applications six weeks after planting and before tasselling. Two hand weedings were carried out by the farmers during the crop cycle. The trials were jointly monitored by the farmers, local extension agents, and the researcher. Data were collected on crop-stand count two weeks after germination, on growth vigour, and grain yield per plot. Beans were harvested 90 to 100 days after planting, while maize was harvested approximately 200 days after planting. Observations were made in farmers' fields on topography, cropping history, soil type, symptoms for P and N deficiency, and indicator plants for soil fertility and infertility. The pH was measured using pHydion Paper Dispenser (3.0–7.5). Data were taken on maize and bean yields per plot. The collected data were subjected to statistical analysis and analysis of variance (ANOVA).

RESULTS

There were six treatments, ranging from no inputs to the maximum of 60-60-0 (N-P-K) kg/ha. Nutrient sources were CAN 27% for nitrogen and TSP 46% for P₂O₅. The two sites were diverse in terms of topography, soil type, etc. (table 1).

Table 1. Characteristics of the Trial Sites

Characteristic	Site 1	Site 2
Topography	Rugged sloppy highlands	Undulating highlands
Cropping history	Maize-beans	Maize-beans
Soil type	Sandy loam	Clay loam
Soil pH	4.5–5.0	5.0–5.5
N, P deficiency symptoms	Present	More N deficiency
Common weeds	Oxalis	Oxalis, couch grass

Analysis of variance indicated significant differences ($p < .05$) in yields of beans and maize between sites, between seasons, and among treatments. There was no significant interaction between sites and treatments. There were interactions between seasons and sites in maize yield, but not in beans. There were significant interactions between seasons and treatment in the yield of maize, but not in beans.

Site 2, Ebwalii, had slightly higher bean yields than site 1, Lusiola. The fertiliser rate of 50-50-0 NPK kg/ha gave the highest yield in both sites but was not significantly different from the fertiliser rate of 50-25-0 and 60-60-0 (table 2). Plots with no fertiliser application gave the lowest yield for both sites. In site 1, only plots with no fertiliser were different from the rest of the plots.

Bean yields were higher in season 2 (short rains) than in season 1 (long rains) , table 2.

The fertiliser rate of 25-25-0 gave the highest bean yields in season 1, but this was not significantly different from the rest. The rate of 50-50-0 gave the highest bean yields in season 2 (not significantly different from the 60-60-0 rate). Plots with no fertiliser gave the lowest yields overall. Season 2 had significantly higher maize yields than season 1. The fertiliser rate of 60-60-0 gave the highest maize yields in season 1 (not significantly different from the rest); 50-50-0 gave the highest maize yields in season 2 (not significantly different from the yield given by 25-50-0 and 50-50-0). The bean yield was higher in site 2 than site 1 for both seasons.

Table 2. Yields of Beans and Maize (kg/ha) for Different Treatments, by Site and Season

Treatment Fertiliser (kg/ha)	Site 1		Site 2	
	Bean	Maize	Bean	Maize
0-0-0	433 c	1900 b	538 b	2153 b
25-25-0	648 b	2980 a	853 a	2807 b
25-50-0	626 b	2708 ab	840 a	3556 ab
50-25-0	706 ab	3048 a	824 a	4582 a
50-50-0	860 a	3411 a	1026 a	3262 ab
60-60-0	826 ab	4311 a	940 a	2764 b
Mean	683	2910	839	3187
c.v. (%)	30	31	27	33
	Season 1 (long rains)		Season 2 (short rains)	
0-0-0	524 a	1611 c	440 d	1268 a
25-25-0	626 a	3111 bc	8817 c	1415 a
25-50-0	611 a	2820 ab	797 c	1596 a
50-25-0	535 a	4033 a	940 bc	1458 a
50-50-0	527 a	3778 ab	1235 a	1445 a
60-60-0	593 a	3111 bc	1111 a	1625 a
Mean	570	3244	890	1470
c.v. (%)	24	37	30	34

DISCUSSION

The average yield of beans and maize obtained in the trial are within the range obtained in earlier FURP trials within the district. Plots with no fertiliser application gave the lowest yield of beans and maize yields for both sites, indicating the need to replenish soil nutrients to improve maize and bean production in the trials areas. Lusiola (site 1) produced lower yields of beans and maize than Ebwali (site 2) because of the sand loam soils and comparatively lower soil pH (4.5 -5.0). Acidic conditions fixed the phosphorus from the fertiliser and make it less available to the plants. There could also be more nitrogen loss through leaching from the top soil in the predominantly sandy soils.

The highest maize yield in Lusiola was obtained from fertiliser rate of 60-60-0; however, this yield was not significantly different from the next highest yield obtained from the 25-50-0 rate. Considering the cost of fertiliser, the rate of 25-50-0 is more economical. The fertiliser rate of 50-25-0 NPK gave the highest maize yield in Ebwali, similar to the rates of 50-50-0 and 60-60-0, indicating that it is a more economical rate for producing maize and beans at the site.

There were higher yields of both maize and beans in the short-rain season than in the long rains. This could be because of adverse weather conditions during the long rains (for example excess rainfall, resulting in leaching of nutrients, heavy infestations, or diseases). The results are contrary to results obtained in FURP trials and may need further verification. Farmers in Vihiga District have, however, reported obtaining higher bean yields during the short rains than the long rains due to disease.

CONCLUSION

Farmers in Lusiola and Ebwali can produce reasonable yields of maize and beans using lower fertiliser rates than the currently recommended rate of 60-60-0 NPK.

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EFFECTS OF SOIL TEMPERATURE ON NODULATION, PHOTOSYNTHESIS, AND DRY-MATTER YIELD OF BEANS AND COWPEAS

S. K. Kimani and B. A. Osborne

ABSTRACT

*In Eastern Africa, Kenya is the major producer of beans (*Phaseolus vulgaris*) with over 500,000 ha planted to the crop. However, there are many problems, including low-yielding varieties, low soil fertility, pests, and diseases. There is a need to understand how the low soil fertility can be alleviated, in addition to understanding the role of plant nutrition, particularly phosphorus (which has been found to be a major constraint in bean production) and cattle manure on nodulation and nitrogen fixation, which could lead to better production methods. This paper discusses research trials conducted over a period of seven years on the effects of water supply on photosynthesis, bean nodulation, and yield. It also discusses the effects of P and cattle manure on nitrogen fixation and yield. Intercropping beans with maize increased the proportion of fixed N, but not in amounts large enough to replenish whole systems. Manure was only effective as a soil fertility amendment during the second growing season, suggesting nutrient immobilisation and the need to integrate manure with inorganic fertilisers as a production strategy.*

RÉSUMÉ

*Le Kenya, principal producteur de haricots (*Phaseolus vulgaris*) d'Afrique de l'Est, consacre plus de 500 000 ha à cette culture. Cependant, les problèmes sont nombreux, notamment l'existence de variétés à faible rendement, la pauvreté des sols, les ravageurs et les maladies. Il est donc nécessaire de rechercher comment remédier à la faible fertilité des sols, de comprendre la nutrition de la plante, en particulier le rôle du phosphore (une des principales contraintes de la production du haricot) et du fumier sur la nodulation et la fixation de l'azote, afin de concevoir de meilleures méthodes de production. Ce document étudie les essais de recherche effectués durant sept ans sur les effets de l'alimentation en eau sur la photosynthèse, la nodulation du haricot et les rendements. Il examine également les effets du phosphore et du fumier sur la fixation de l'azote et sur les rendements. Les cultures associées de maïs et de haricots augmentaient la proportion de phosphore fixé, toutefois dans des quantités insuffisantes pour permettre de reconstituer les systèmes dans leur intégralité. Le fumier était un amendement efficace seulement pendant la seconde période de végétation, suggérant l'immobilisation des nutriments et la nécessité d'associer fumier et fertilisants minéraux.*

INTRODUCTION

In Eastern Africa, Kenya is the major producer of beans (*Phaseolus vulgaris*), with over 500,000 ha planted to the crop. However, production is beset by many problems, including low-yielding varieties, low soil fertility, pest infestations, and diseases. Beans and cowpeas (*Vigna unguiculata*) are important leguminous crops in semi-arid regions of Kenya, where they are mainly intercropped with maize (Nadar and Faught, 1984). In these regions, soil N levels are often low, and these two nitrogen-fixing legumes can be used to recycle and sustain soil nitrogen within the agricultural cropping system, provided that both form an effective nitrogen-fixing symbiosis. However, nodulation in *Phaseolus vulgaris* can be highly variable and nitrogen fixation is generally lower compared to that of cowpeas (Graham, 1981). In the semi-arid regions, bean nodulation in the field is poor (Kimani, 1994). The inability to form nodules under hot, arid field conditions could be related to water shortages, high soil-surface temperatures, or salinity. In these regions, *Rhizobium* populations may also be low (Ssali, 1981; Karanja and Wood, 1988).

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Previous work in semi-humid areas of Kenya with marginal rainfall indicate that cowpeas sometimes perform better than beans with regard to nodulation, N fixation, and dry-matter production (Nadar, 1984), although the mechanistic explanation for this is not known. In this paper, the effects of soil temperature and watering on nodulation, photosynthesis, leaf-water potential, and dry-matter yield in beans and cowpeas were examined.

MATERIALS AND METHODS

Experimental design

The experimental design was a randomised complete block with three replicates: 48 pots (8 cm in diameter by 15 cm in length) were filled with $300\text{g} \pm 0.05\text{g}$ of air-dried soil (approximately 15% moisture content). The soil was an Acric-Orthic Ferrasol from Kiboko, a semi-arid area of Eastern Kenya, sampled from a depth of 0 cm to 20 cm. Demineralised deionised water was added in equal volumes to all pots to initial volumetric water content of 25%, which is the estimated value of the soil field capacity. Using Hamblin's (1981) filter-paper method, this soil moisture content is equivalent to -0.015 MPa.

After wetting, the soil settled in the pots, leaving about 4 cm of pot bare. Twenty-four pots were placed in a water bath and were suspended using an aluminium grill, leaving approximately 2.5 cm of the pot above the water. The water temperature was set to 40°C during the day (8:00 a.m. to 5:00 p.m.) and 25°C for the rest of the time. Another set of 24 pots was placed on a glasshouse bench where average temperatures were 24°C during the day and 14°C night. In each set of 24 pots, 12 were sown with beans and 12 with cowpeas. Six pots with beans and another six pots with cowpeas were watered to field capacity by applying about 20 cm^3 of water daily. This is subsequently referred to as the 'well-watered treatment'. The rest were watered once a week with a total of 40 cm^3 of water per pot, which was equivalent to a soil moisture content 6% to 10% (-7.2 to -5.91 MPa). These treatments are referred to here as the 'water-limited treatment'.

Measurements

Net photosynthesis was measured on the youngest fully expanded trifoliate leaf during the early vegetative and flowering to pod-filling stages using an infrared gas analyser (IRGA) ADC LCA-3 (Analytical Development Co. Ltd., Hoddesdon, Hertfordshire, UK), operated in an open system. The primary leaves were used for the measurements at the seedling stage. At other growth stages, the youngest fully expanded trifoliate leaf was used in the measurements. After measuring photosynthesis, measurements of leaf-water potential were made on the same leaves using a pressure chamber (PMS Instruments Co., Corvallis, Oregon, USA). Leaf area was determined by the leaf disc method, taking 15-25 leaf cores (approximately 19.625 mm^2) from the plants. The dry weight of these samples was then related to the total leaf area of the cores. This in turn was then related to the total leaf dry weight of the treatment sample to determine the total leaf area. Sampling for nodule counts was done at 10, 22, and 42 days after sowing. Roots were collected by washing the root-containing soil through a 0.45 mm sieve, after which nodules were counted. At 42 days after sowing, shoots and roots were dried in a forced-draft oven at $65-70^{\circ}\text{C}$ for 48 hrs, after which dry weights were determined. Total nitrogen analysis was done on the shoots using the micro-Kjeldahl method, as described by Anderson and Ingram (1993).

RESULTS AND DISCUSSION

Well-watered plants had higher leaf-water potentials at all sampling dates, compared to plants where water was withheld. Cowpeas in general had higher leaf-water potentials than beans. At the seedling stage (10 days after sowing), neither watering nor high root temperatures had an effect on leaf-water potential. At the vegetative stage (22 days after sowing) and at the flowering/pod-filling stage (42 days after sowing), plants grown at high root temperatures, where water was withheld, had significantly ($p \leq 0.05$) lower leaf-water potentials than the controls, with cowpeas having a lower leaf-water potential than beans (table 1).

At the time of the first sampling (10 days after emergence), only the watered cowpea plants in the higher-temperature treatment contained nodules (table 2). At the second sampling (22 days after emergence), well-watered plants grown at the higher root temperatures had more nodules than the other treatments and the cowpeas had a larger number of nodules than the beans. Surprisingly, water-limited plants grown at the higher root temperature formed higher numbers of nodules in cowpeas than in beans. In the lower-temperature treatment, only the cowpeas formed nodules in all cases (table 2). At the final harvest (42 days after sowing), plants grown in the higher rooting temperature formed significantly ($p \leq 0.05$) more nodules than the plants grown at the lower rooting temperature, and beans had more nodules than cowpeas (table 2).

Table 1. Leaf-Water Potentials (Mpa) at 22 and 42 Days after Sowing

	Days after sowing			
	22 days		42 days	
	LT	HT	LT	HT
Watered bean	- 0.05	- 0.06	- 0.10	- 0.12
Watered cowpea	- 0.06	- 0.07	- 0.14	- 0.15
Water-limited bean	- 0.11	- 0.25	- 0.20	- 0.25
Water-limited cowpea	- 0.30	- 0.34	- 0.40	- 0.45
LSD (0.05)	- 0.14		- 0.11	

Note: LT indicates 40/25°C and HT indicates 27/15°C.

Table 2. Nodule Numbers per Plant and Shoot Dry Weight, Root Weight, and Leaf Area in Beans and Cowpeas Grown at Two Root Temperatures

Treatment	Days after emergence			SDWT** (g/plant)	RWT** (g/plant)	Leaf area** (cm ² /plant)
	10*	22*	42*			
40/25°C						
Well-watered beans	0	4.5	41.67	1.30	0.23	2551.85
Water-limited beans	0	1.6	5.11	0.54	0.16	1401.43
Well-watered cowpeas	2.25	28.0	32.11	1.34	0.25	2863.39
Water-limited cowpeas	0	18.0	7.01	0.64	0.17	1615.16
27/15°C						
Well-watered beans	0	1.40	30.8	1.41	0.27	2817.32
Water-limited beans	0	0	0	0.67	0.18	1492.05
Well-watered cowpeas	0	13.25	21.33	1.65	0.30	3448.11
Water-limited cowpeas	0	0	0	0.83	0.20	1503.78
LSD (0.05)	0	0	0.12	0.03	0.012	141.50

*Each value is a mean of three replicates.

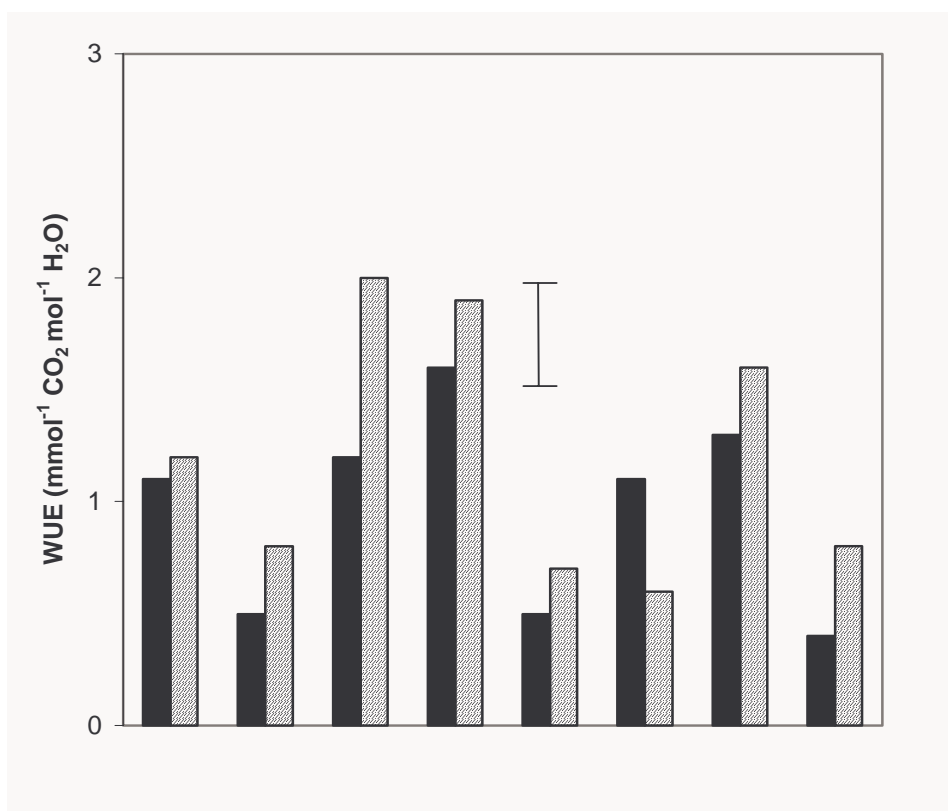
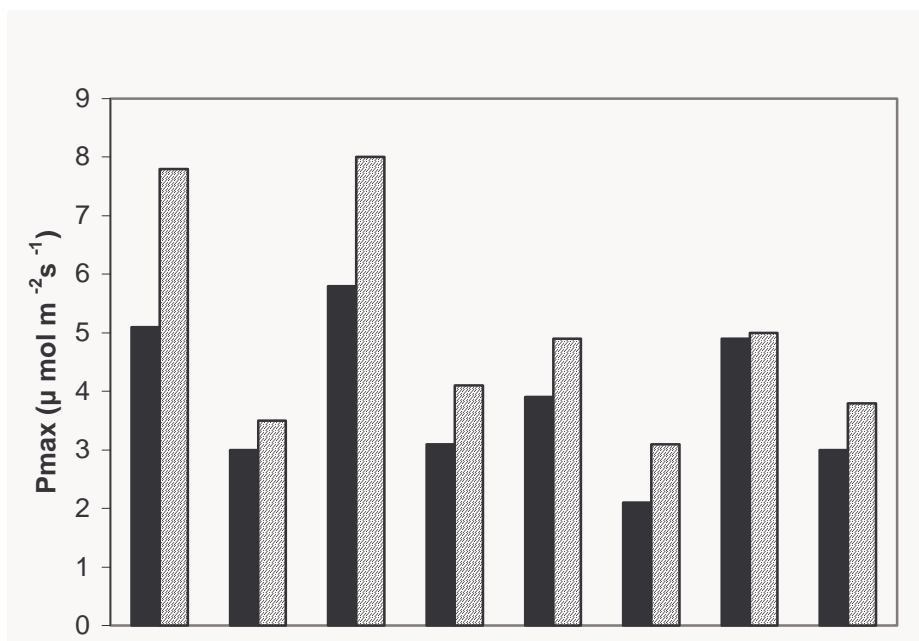
**Collected 42 days after emergence; SDWT is shoot dry weight; RWT is root weight.

High rooting temperatures lowered the photosynthetic rates in both beans and cowpeas. In bean plants grown at the higher root temperature, where water was withheld, the photosynthetic rate saturated at a lower irradiance at both growth stages. In all cases, the cowpea plants had a higher P_{max} and higher instantaneous water-use efficiency (WUE) than the beans (figure 1).

At final harvest, the well-watered plants had significantly ($p \leq .05$) higher total dry matter than did the plants where water was withheld (table 2). Plants grown at the higher root temperature had lower dry weights than the control. In general, roots contributed approximately 15%-16% of the total plant dry weight in well-watered plants and 19%-22% in plants where water was withheld. This showed that water shortages favour roots at the expense of shoot growth.

At the seedling stage, the nitrogen contents of the shoots of plants grown at the higher root temperature were higher in the watered treatment than in the control. Cowpeas had higher nitrogen contents than beans, although this was not statistically significant. At the flowering/pod-filling stage, nitrogen content was higher in both species relative to the earlier growth stages. These increases in nitrogen were more pronounced in cowpeas than in beans (table 4).

It should be noted that the water-deficit and high temperature treatments used in this experiment might not be strictly comparable to what actually happens under field conditions. For instance, in the field there is a sharp gradient in soil temperature down the soil profile, and the surface (0 to 5 cm) experiences the greatest fluctuations in temperature. In addition, plants experiencing water shortages in the field have a relatively longer period of adjustment, compared to water withheld under controlled conditions, as in this study.



Legend

well-watered beans (BWC),
water-limited cowpeas (CDC).

water-limited beans (BDC)

well-watered cowpeas (CWC)

The higher rooting temperatures include
well-watered beans (BWHT)
water-limited cowpeas (CDHT)

water-limited beans (BDHT)

well-watered cowpeas (CWHT)

The vertical bar represents LSD (0.05).

Figure 1. (A) Maximum photosynthesis (P_{max}) and (B) instantaneous water-use efficiency (WUE) during the vegetative and flowering to pod-filling stages.

Table 4. Nitrogen content in bean and cowpea at the early vegetative growth stage at flowering to pod filling

Treatment	Nitrogen content (%)	
	Early vegetative	Flowering to pod filling
40/25°C		
Well-watered beans	2.02	2.58
Water-limited beans	1.76	1.94
Well-watered cowpeas	2.40	3.54
Water-limited cowpeas	2.14	2.22
27/15°C		
Well-watered beans	2.08	3.02
Water-limited beans	1.75	1.78
Well-watered cowpeas	2.38	3.28
Water-limited cowpeas	1.96	1.98
LSD (0.05)	0.71	0.92

This study indicates that the absence of nodulation in beans under field conditions (a common phenomenon) may not be due to soil factors or higher root temperatures. Higher nodule numbers were found in beans even at the higher root temperature (40°C), under well-watered conditions. Rather surprisingly for beans, more nodules were actually formed at the higher root temperature where water was withheld. Similar observations were also found with cowpeas. Of the two species examined, more nodules were formed in the cowpeas under limited water at the higher root temperature. This study shows that cowpeas nodulate earlier than beans—in this case, as early as 10 days after sowing—when well watered. Despite the earliness in cowpea nodulation, both species showed the largest number of nodules at 42 days after sowing, where beans actually had more nodules than cowpeas (table 2). This appears to conflict with reports that beans are poor nodulators compared to cowpeas (Graham, 1981). However, growth responses by rhizobia to temperature are influenced by the host species and even cultivars within species (Bowen and Kennedy, 1959; Day et al., 1978). The limitation to nodulation attributable to high soil temperatures varies with rhizobial strains (Day et al., 1978), suggesting that the soil at the field site may have had more strains that would nodulate with beans than with cowpeas.

Of the two major factors that could limit nodulation (inadequate soil moisture and high soil temperatures), low water availability appears to be more important. The surface soil temperatures in the field site where the soils were sampled can be as high as 50°C. Greenhouse studies have shown that the maximum root temperatures for optimum nitrogen fixation by the common bean are 30°C, whilst in cowpeas it is 33°C (Graham and Halliday, 1977). In our study, with 40/25°C day/night temperatures, the plants operated above these optimums during the day. Despite this, at the higher root temperature, both species formed more nodules when they had a good water supply, indicating that high root temperatures may not be a limitation to nodulation in beans and cowpeas grown in Kiboko soils.

Water supply affects nodulation and nitrogen fixation, with a greater effect on nodule function than on nitrate uptake (Sau and Miguez, 1990; Rawsthorne et al., 1985). A decrease in soil-water potential from -36 to -360 kPa significantly decreases the number of infection threads formed and completely inhibits nodulation (Worrall and Roughley, 1976). Even after infection, a reduced water supply can inhibit nodule function (Gallacher and Sprent, 1978) and accelerate their senescence (Sprent, 1976). This work indicates that the decreased water supply affected nodule formation, with less of an effect at higher soil temperatures. There is evidence that cowpeas are less sensitive to drought, compared with other grain legumes, such as beans (Summerfield and Roberts, 1985). This has often been attributed to their longer growth cycle. Beans usually flower after approximately 30 days while cowpeas flower at 35 days after sowing. Shortly after flowering, competition for photosynthate between nodules and pods becomes important (Piha and Munns, 1987). Since beans have their maximum nodulation later in the growing season, they are therefore more likely to be handicapped by the shortness of the period in which photosynthate is available for fixation due to competition with pod formation and grain filling. Although we did not measure nitrogen fixation in this study, examination of the nodules showed a pink colouration in some, suggesting that in both the cowpeas and beans there could have been some fixation at higher soil temperatures and low water availability. Even under favourable conditions, the bean is reported to be a lower nitrogen fixer compared to cowpeas (Graham, 1981). The earlier nodulation in cowpeas suggests, therefore, that the cowpea could have an advantage (in

terms of the availability of fixed N) earlier in the season before the greater competition for photosynthate becomes apparent during the pod-formation and grain-filling stages.

Photosynthesis was influenced by both the soil temperature and moisture content; however, soil temperature had no effect on the photon yield (Φ_i) (mol CO₂/mol photon). While watering had no effect on bean photon yield (Φ_i), at the early stage of vegetative growth, where Φ_i was 0.02, there was an increased photon yield in cowpeas: Φ_i was 0.03 in the watered plants and 0.02 in the plants with limited water. The maximum photosynthetic rate (P_{max}) was 8.0 $\mu\text{mol}/\text{m}^2 \text{ s}^{-1}$ in watered cowpeas and 7.5 $\mu\text{mol}/\text{m}^2 \text{ s}^{-1}$ in watered beans. After water was withheld, P_{max} was lowered to 3.0 $\mu\text{mol}/\text{m}^2 \text{ s}^{-1}$ in cowpeas and to 2.8 $\mu\text{mol}/\text{m}^2 \text{ s}^{-1}$ in beans. The high soil temperatures reduced P_{max} to 5.0 in watered cowpeas and 4.5 in beans, with no marked watering effect on P_{max} in beans. However, cowpeas had significantly ($p \leq .05$) higher dry weight than beans, despite the small differences in leaf photosynthesis. The irradiance at which P_{max} occurs is lower in beans than in cowpeas under conditions of withholding water at high root temperatures (Kimani, 1994). This suggests that on withholding water at high root temperatures, there is a greater decline in photosynthesis in beans than in cowpeas. This was not associated with differences in leaf-water potential. Cowpeas had higher P_{max} despite the lower bulk leaf-water potentials (table 1). The greater photosynthesis in cowpeas, compared to beans, possibly resulted in the production of greater leaf area and higher dry weights (table 2), and possibly, higher nitrogen assimilation.

CONCLUSIONS

This study confirms that cowpeas have the ability to perform better than beans under extreme conditions of water shortages and high root temperatures. The high root temperature in this study lowered the photosynthetic rates in both beans and cowpeas. In all cases, the cowpea plants had higher maximum rates of photosynthesis (P_{max}) and higher instantaneous water-use efficiency (WUE) than the beans.

At higher root temperatures, both beans and cowpea species formed more nodules when there was a good water supply, indicating that high root temperatures may not be a limitation to nodulation in beans and cowpeas grown in the soils extracted from the semi-arid area of eastern Kenya at Kiboko.

On withholding water at high root temperatures, there is a greater decline in photosynthesis in beans than in cowpeas. The greater photosynthesis in cowpeas compared to beans possibly resulted in greater leaf area production and higher dry weights. This study therefore supports the suggestion that cowpeas have the ability to perform better than beans under extreme conditions of water shortage and high root temperatures.

The study supports the need for breeders to come up with bean varieties that will perform better under water-limited conditions and higher temperatures.

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INTEGRATING GREEN MANURE COVER CROPS IN SMALL-SCALE AFRICAN FARMING SYSTEMS: SUCCESS, CONSTRAINTS, AND OPPORTUNITIES IN EASTERN UGANDA

Richard Miiro, Anthony Esilaba, and Sonii David

ABSTRACT

This paper reports on a study to investigate the integration of green-manure cover crops (mucuna, lablab, and crotalaria) in the farming systems of farmers who were involved in participatory research activities with CIAT. Conducted in July 2000 in eastern Uganda, the study used structured and semi-structured interviews, as well as focus-group discussions involving 53 households (including participating farmers, their neighbours, and farmers who had dropped out of the participatory activities). Results indicated consistent use of the green-manure cover crops for seven seasons. Reasons included the ability to restore soil fertility in a short time, presence of support technologies (cassava resistant to mosaic virus, maize, bean seed, tephrosia, canavalia, vetiver grass), and selling green-manure seed. Farmers reported improved food security and income, but there was little on-farm expansion due to lack of land. Constraints to the integration of green-manure crops included drought, labour bottlenecks, and lack of lablab and crotalaria seed because of harvesting and storage problems. The paper discusses adaptations made by participant farmers, non-agronomic innovations, seed systems, and diffusion of the green-manure cover crops. Reasons for the lack of adoption of the green manures by farmers who dropped out and neighbouring farmers are also discussed.

RÉSUMÉ

Une étude menée en juillet 2000, dans l'est de l'Ouganda, visait à déterminer la part des engrais verts en dérobée (mucuna, lablab et crotalaria) dans les systèmes de culture de cultivateurs prenant part à des activités de recherche participative avec le CIAT. Cette étude s'est appuyée sur des interviews structurées et semi-structurées, ainsi que sur des discussions de groupe auxquelles participaient 53 familles (celles des cultivateurs participants, de leurs voisins ainsi que des agriculteurs s'étant retirés du projet). Les résultats indiquaient une utilisation constante des engrais verts en dérobée pendant sept saisons qui s'expliquait par l'aptitude de ce type d'engrais à rétablir la fertilité des sols en peu de temps, la présence de technologies de soutien (manioc résistant au virus de la mosaïque, maïs, semences de haricots, tephrosia, canavalia, herbe de vétiver) et par la vente de semences d'engrais verts. Les cultivateurs ont fait part d'une amélioration de la sécurité alimentaire et d'une augmentation de leurs revenus, mais le manque de terre a limité l'expansion en situation réelle. Les problèmes de main d'œuvre et le manque de semences de lablab et de crotalaria dû à des problèmes de récolte et d'entreposage ont également fait obstacle à l'intégration des engrais verts. Le document examine les adaptations effectuées par les cultivateurs participants, les innovations non agronomiques, les systèmes semenciers et la diffusion des engrais verts en dérobée. Les motifs de l'adoption insuffisante d'engrais verts de la part de cultivateurs s'étant retirés du projet et d'agriculteurs des environs sont également examinés.

Key words: *Integration, Adaptation, Diffusion*

INTRODUCTION

Increasing soil-nutrient depletion and decreasing soil fertility and crop yields are common features of farming in sub-Saharan Africa (Smaling et al., 1997; Stoerovogel and Smaling, 1990). Integrated nutrient management (INM) strategies have been considered promising options for soil fertility management because of their suitability under local biophysical, economic, and social conditions (Smaling et al., 1997; Smaling et al., 1996). INM technologies bridge the gap between high external-input agriculture and the extreme forms of

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traditional, low external-input agriculture and are therefore recommended for the majority of resource-poor farm households that form the majority of farmers in eastern Uganda (Miïro et al., 2001), an area characterised by high population density and continuous cultivation with minimal nutrient replenishment and reduced fallow periods.

Green-manure cover crops and shrubs, such as crotalaria (*Crotalaria ochroleuca*), mucuna (*Mucuna pruriens*), and lablab (*Dolichos lablab*), were introduced in Imanyiro sub-county in the Iganga District of eastern Uganda between 1994 and 1996 as an alternative technology for improving soil fertility to increase crop yields and control weeds in maize-bean cropping systems (Wortman et al., 1998). A decision guide for the green-manure cover crops was developed to enhance dissemination of the technology, which involved government extension staff, NGOs (like the Africa 2000 Network/UNDP), and other institutions dealing in agriculture (Fischler and Wortmann, 1997; Wortmann et al., 1999).

Fischler and Wortman (1997) reported that the technologies for the green-manure cover crop were adapted by farmers in a number of ways, such as planting mucuna at the same spacing as maize so that after uprooting the cover crop, the maize would be planted in the same holes. Canavalia was reportedly experimented with as a green manure in maize and beans and as a cover crop in bananas. Crotalaria was grown in young cassava, coffee, and pineapple and used as mulch. Crotalaria seed was mixed with bean seed to control bean bruchids, and its leaves served as a vegetable (Wortmann et al., 1999). To support the participatory process, some technologies, such as seeds of improved varieties of cassava, maize, and beans were also introduced, and farmers were assisted to form a credit society.

About four years (1996-2000) have passed since the three green-manure cover crops (crotalaria, mucuna, and lablab) were recommended and disseminated to farmers in the area. The use, integration, scaling-up, and diffusion of the green-manure cover crops, as well as constraints, needed to be determined. An empirical study to assess the integration and adaptation of the green-manure cover crops among participant farmers was required, along with insights into the initial overflow effects to neighbours and other farmers. Research questions included the following: To what extent had green-manure cover crops been integrated and adapted within the farming systems of the farmers who participated in the research? What reasons led to the integration? Was there any on-farm scaling-up and spreading of the technologies to other farmers? What were the benefits and constraints of using the cover crops? What were the reasons for the spread of the green-manure crops or other related technologies? How were the neighbours and dropout farmers affected by the technologies? To what extent had dissemination of the technologies taken place. The research was undertaken when the CIAT project on improving integrated nutrient management practices on small-scale farms in Africa using a participatory learning and action research (PLAR) process was in progress.

METHODOLOGY

The study was conducted in five villages from Buyemba and Mayuge parishes in Imanyiro sub-county, eastern Uganda. The target population included all the farmers who participated in the trials and were still using the green-manure cover crops, farmers who had dropped out of the trials, and neighbouring farmers. The sample size consisted of 21 participant/continuing farmers, 22 neighbours, and nine participating farmers who had dropped out, bringing the sample size to 52. Focus-group discussions (FGDs) were held with two separate groups of six participating men and six participating women to understand the dynamics of the green-manure crops in the farming community. In addition, a formal survey questionnaire was administered to both participating and nonparticipating farmers to capture variables of interest, such as trends in using the green-manure cover crops, technology adaptation, diffusion of the technologies, seed management, labour and the respondent's socio-economic status.

The study covered farmers' experiences between 1994 and 1996. Survey data were analysed using simple descriptive measures, and comparison statistics assisted in desegregating the different crops, farmer groups, time differences, and other variables likely to affect the integration, scaling-up, and spreading of the technologies.

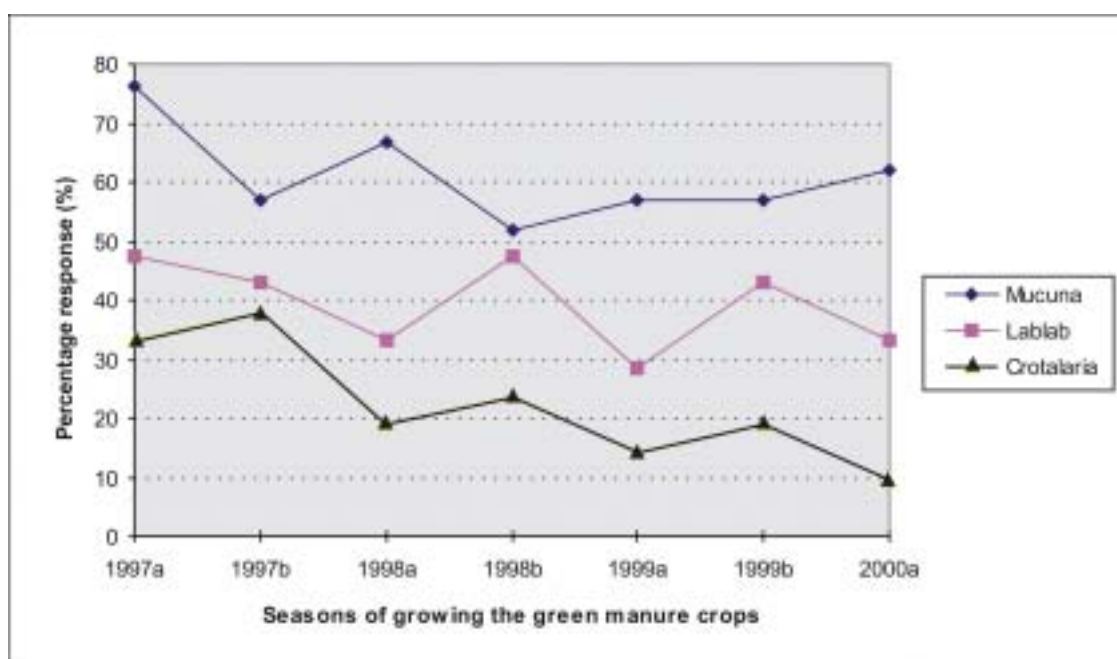


Figure 1. Trend of growing green-manure cover crops by participant farmers between the seasons of 1997A and 2000A

RESULTS AND DISCUSSION

Integration of green-manure cover crops into farming systems of participant farmers

The consistent use of the green-manure crops by the farmers who participated in the original experiments was established by determining the proportion of farmers who grew mucuna, lablab, and crotalaria between the long-rains (season A) of 1997 to season A of the year 2000 (figure 1):

- Mucuna registered a high level of continued use (76.2%) after the trials (season 1997A). By season B of 1998, the proportion of those who continued with the crop had decreased to 52%; it then increased gently to 57% for seasons A and B of 1999, to 62% for season 2000A (figure 1). The mean percentage of the 15 farmers who grew the crop over the seven seasons was 80%.
- About 47.6% of the participant farmers continued to use lablab after the trials (1997A). The proportion of those growing it went down to 42.9% in 1999B and to 33.3% in 2000A. There was some intermittent reduction in the proportion of lablab growers for the seasons of 1998A (33.3%), and 1999A (28.6%). The mean percentage of the 10 farmers who grew the crop over the seven seasons was 82%.
- Thirty-three percent of the farmers were growing crotalaria in 1997A, which increased to 38% in 1997B. In 1998A, only 23.8% of the farmers grew the crop, followed by 19% in 1999B, to only 10% in 2000A. The mean percentage of the seven farmers who grew the crop over the seven seasons was 62%.

Figure 2 shows changes in the level of soil fertility of farmers' fields at all topographical levels (along the catena) after growing one, two, or all three of the green-manure cover crops, as perceived by the farmers.

- Of the 23.8% farmers who had land at the hilltop, 19% indicated that before using the green-manure cover crops the fertility of soils was poor, while 4.8% said it was average. After using the green-manure cover crops, all the farmers (23.8%) whose land was on the hilltop reported that their soil was fertile.
- About 62% of the farmers had their land situated on flat terrain. Before using the green-manure cover crops, 9.5% of these said that their fields had very poor soil fertility, 33.3% indicated poor soil fertility, 4.8% average, and 14.3% said their soils were fertile. After using the cover crops, 14.3% of the farmers with fields on flat terrain indicated that their soils were very fertile, 42.9% said the soils had become fertile, while 4.8% said their soils were of average fertility.
- About 10% of the farmers had fields on gentle slopes; 4.8% said their fields had very poor soil fertility and another 4.8% had a poor soil fertility level before using the green-manure cover crops. Both of

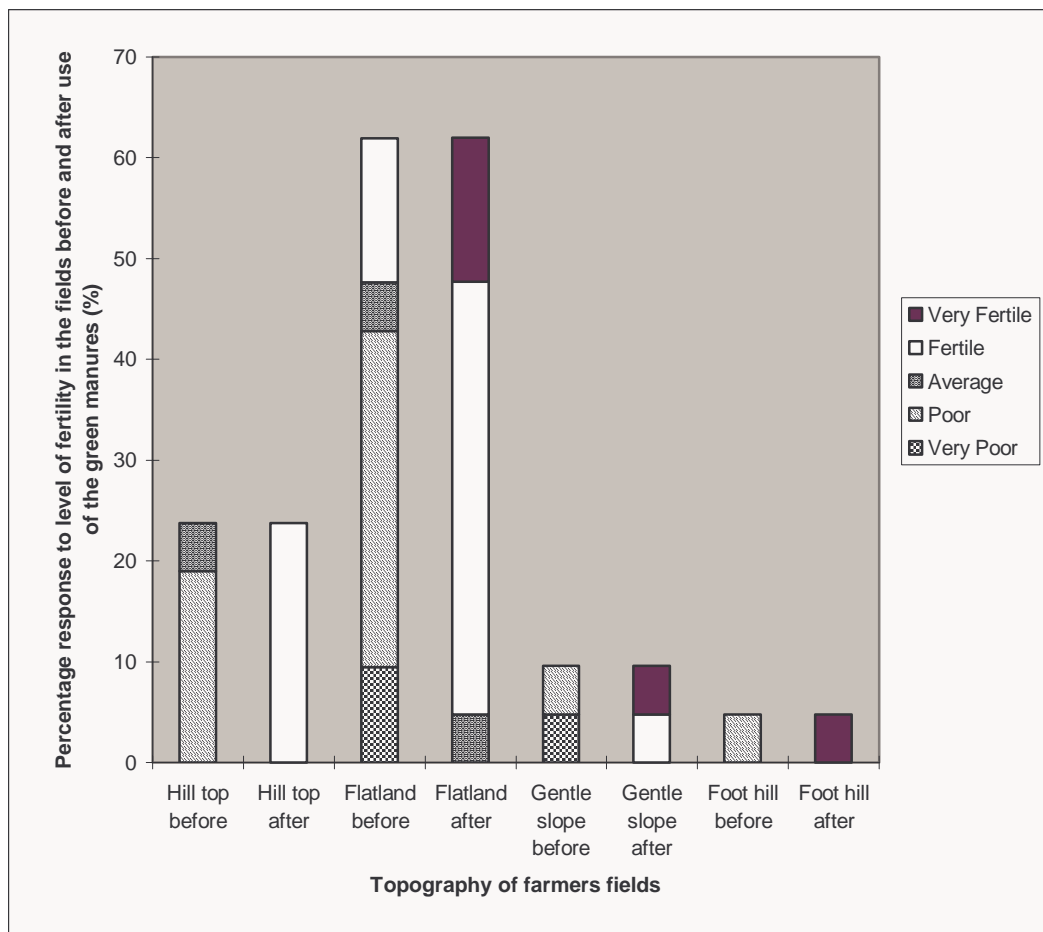


Figure 2. Level of soil fertility before and after planting green-manure cover crops along the catena of farmers' fields

these proportions indicated a change of the fertility to fertile and very fertile, respectively, after using the green-manure cover crops.

- The farmers (4.8%) who had their fields at the foothills indicated a change in soil fertility from poor to very fertile after using the cover crops.

Factors that affected the integration of the green-manure technologies

All farmers who participated in the original trials and were part of the study indicated that they were continuing to use one, two, or all three of the green-manure cover crops. The main reason given for continuing was their key role in restoring soil fertility. Other reasons included (1) the provision of complimentary technologies such as cassava and banana planting materials, bean seed, and agro-forestry tree species as incentives to encourage farmers to attend to the experiments, but also as part of a systems approach to solving the other problems farmers had raised. (2) The use of participants' indigenous technical knowledge—farmers reported that during the trials they were encouraged to suggest locally known solutions to the identified problems. (3) The sale of the green-manure seed from the trials—farmers indicated that seed was bought by the research team to encourage farmers to attend to their experiments, especially seed harvesting, which was a difficult activity. The seed sales encouraged intensified growing of the cover crops for seed. Unfortunately, not all the seed was purchased. (4) The use of the cover crops for other purposes, such as livestock feed.

Constraints of integrating the green manure cover crops in to the farming systems

According to the 21 participating farmers, the main constraint to growing the green manure was the prevailing drought conditions, which caused temporary breaks in growing the cover crops. Second, farmers indicated their dislike of the limited use of the cover crops for improving soil fertility and not as food for humans. Farmers also reported that it was difficult to harvest crotalaria seed because successful seed harvesting required the crop to stay longer in the field. There was difficulty harvesting lablab seed because its seed was easily attacked by pests, which farmers controlled by spraying with an artificial pesticide. Whilst

mucuna was fast growing, proliferous, and produced very good-looking seed, the seed was not edible. Mucuna also tends to climb when grown with other crops, resulting in poorer yields from the other crops more labour for removing the overgrowth from other plants such as bananas and coffee. Farmers indicated that mucuna needs a determined person who values its benefits to grow it.

According to the 22 immediate neighbours of the participant farmers, the reasons for not adopting the green-manure cover crops, despite being aware of them, included a lack of adequate information about them, lack of land and time to plant them, lack of seeds, and lack practical knowledge on how to grow them.

Nine farmers were formerly participants but dropped out of the programme. They indicated that they dropped out because leadership problems made it difficult for other farmers to sell their green-manure seed, lack of funds to buy the green manure seed, limited land, land tenure, and social problems. Another reason, given by female participants, was the opening up of a women's credit organisation, funded by the United States Agency for International Development (USAID). This diverted them to business activities other than the green-manure trials. Other reasons included difficulty in scaling-up the cover crops on the small farming land available, failure to realise the objective of growing the green-manure crops for sale, failure to provide credit to the farmers as promised by the research team, and lack of a reliable market for the green-manure seed. However, there was still interest among this group to resume growing the green-manure crops, particularly if they could get seed at an affordable price and a market for the seed, in addition to improving the fertility of their soils.

On-farm scaling-up of green-manure crop use

Over 60% of the participant farmers had not expanded the space planted to green-manure cover crops because of a lack of sufficient land and the need to reserve land for food production. Lack of security of land tenure and labour constraints were the other reasons. However, the green-manure crops were rotated and used as intercrops with food crops. On average, the green-manure crops were planted in the same field 4.4 times, the range was 9, while the standard deviation (SD) was 3.61.

Innovations with the use of green-manure cover crops and other technologies

Forty-three percent of the participant farmers indicated that they had tried using the green-manure cover crops in a new way besides what the researchers had demonstrated during the trials (table 1). Sixty-seven percent of those who used the green-manure crops in new ways had innovated with mucuna, while 22% had innovated with crotalaria, and 11% had done so with tephrosia.

Farmers innovated with crotalaria by using it as a mulch for coffee and incorporating the crotalaria residues into the soil. They also adapted crotalaria seed in storage with beans; it protects the beans from storage pests such as bean weevils. Intercropping mucuna with maize was one of the adaptations made, along with non-agronomic innovations: crushed mucuna seed was experimented with as a poultry feed, dried mucuna leaves were mixed with maize bran to make chicken feed, while fresh vegetation was used as feed for goats and cattle. The major innovation with lablab was using it as human food by eating its leaves—both as a fresh and a processed/dried vegetable. The seeds were also boiled like the common bean and eaten as a source of protein. Canavalia was intercropped with coffee, maize, and bananas. Vetiver grass, which was meant to stabilise soil bunds against soil erosion, was used as thatching for houses.

Farmers made sure that they had enough seed of the green-manure crops by saving from the previous harvests (figure 3). Sixty-seven percent of the farmers indicated that they saved mucuna seed, while 24% indicated that they saved lablab and crotalaria seed. However, 75% of the farmers indicated having obtained seed from other farmers (46% for mucuna and 55% for lablab). The average number of occasions on which they did this was 1.36, SD of 0.5, and a total of 17 times.

Eighty-one percent of the participant farmers indicated that they had sold some of their green-manure seed. Forty-seven percent had sold seed to the leader of the Farmer Participatory Research Group, while 24% had sold to CIAT, and 6% to their fellow farmers. Eighty-nine percent of the participating farmers who had sold green-manure seed had sold mucuna seed, while 38% had sold lablab and crotalaria each. Mucuna was sold at an average price of \$0.52/kg (at the exchange of 1,750 Ugandan shillings per US dollar), with a range from \$1.70 to \$0.28. The price for lablab seed ranged from \$5.71 to \$1.14, with an average of \$3.23/kg. Crotalaria seed was sold at a mean price of \$1.71/kg.

Table 1. Farmer Innovations with the Green-Manure Cover Crops and Other Technologies

Green-manure crop	Recommended method of use	Modification in method of use	Non-agronomic modifications
Crotalaria	<ul style="list-style-type: none"> • Intercrop with maize or as a one-season fallow crop • When mature, uproot and mulch in maize, beans, sorghum, millet, cotton, etc. • Thresh pods to get seed • Mulch 	<ul style="list-style-type: none"> • Ploughing into the soil • Intercrop with beans to control nematodes and other bean diseases • Seed combined with bean seed during storage controls bean storage pests 	<ul style="list-style-type: none"> • Leaves used as a vegetable and as a medicine for stomach pains
Mucuna	<ul style="list-style-type: none"> • Use as a 1-season fallow crop, uproot at planting and mulch in the following crop • Keep seed for future use • Use as cover crop in banana plantations 	Intercrop with maize	<ul style="list-style-type: none"> • Crush seed to make chicken feed • Mix dried leaves with maize bran to make chicken feed • Use fresh vegetation as feed for goats and cattle
Lablab	<ul style="list-style-type: none"> • Grow for 2 seasons as fallow crop, uproot at planting and mulch in the following crop • Use as a fodder crop and as a cover crop in banana plantations 		<ul style="list-style-type: none"> • Seed and the leafy vegetation edible • Seed cooked like beans • Dried and powdered leaves also a source of protein
Canavalia		Canavalia intercropped with coffee, maize and bananas	
Vetiver grass	Grow at soil bunds to control soil erosion		Thatching grass

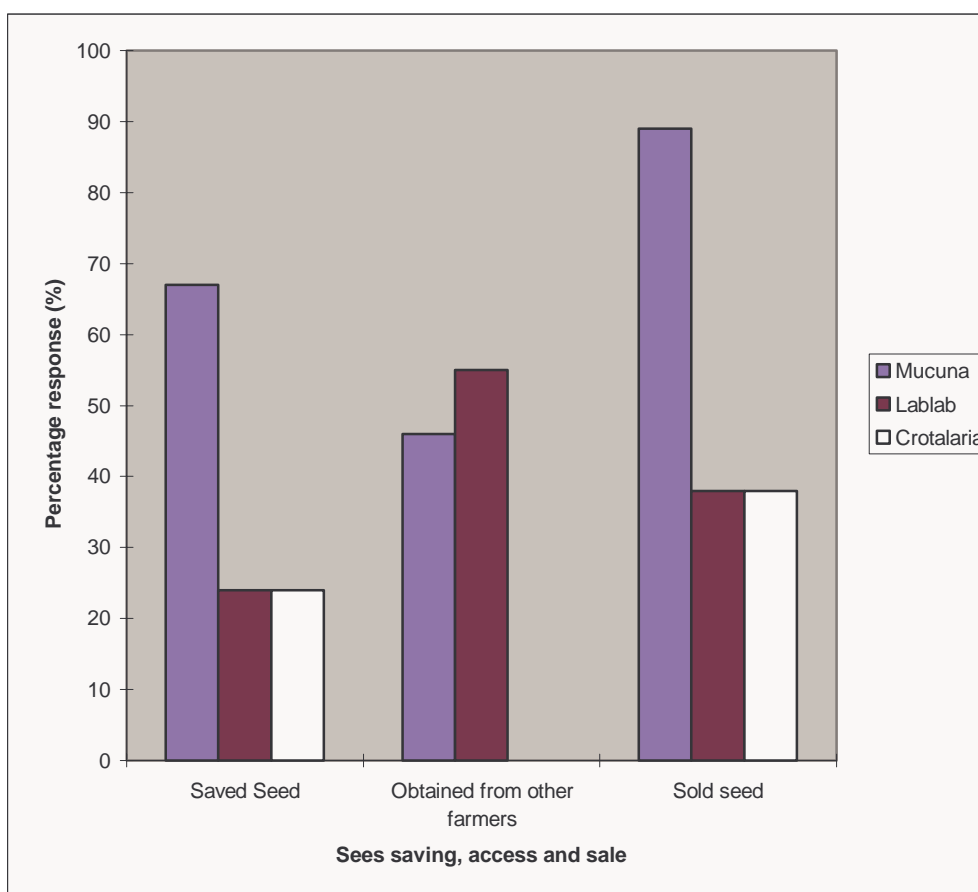


Figure 3. Seed saving of green-manure cover crops, access to and sale of seed among participant farmers

About 1908 kg of mucuna seed was sold, with an average of 159 kg of seed per farmer (SD 423). The total amount of lablab seed sold was 43.5kg, with an average of 10.87 kg of seed per farmer and an SD of 13.37. Twenty six kilograms of crotalaria seed was sold, with an average of 5.2 kg/farmer (SD 3.49).

The Diffusion of green-manure crops

Ninety five percent of the participant farmers had shared information on green-manure crops with other farmers. Each participant had, on average, shared with 17 farmers (total 290 farmers, SD 24.6). Participant farmers gave estimates of other farmers who were using the green-manure crops after sharing with them.

Table 2 Use of Green-Manure Crops by Secondary Farmers, as Told by Participating Farmers

Green manure	Number of respondent farmers	Total number of other users	Mean number of other users	Standard Deviation (SD)	Range
Mucuna	12	86	7.17	6.32	23
Lablab	7	53	7.57	7.74	22
Crotalaria	2	31	15.5	13.44	19

Table 3 shows the frequency and percentage of different members of the household who shared information about the green-manure crops and the people with whom they shared the information. Sixty-six percent of the participants said women in the community were reached most, while 38% felt that the men had been reached most and only 10% felt that children had been reached most. According to 57% of the participant farmers, the most-reached group of farmers were the small-scale peasant farmers, while 43% said subsistence farmers had been reached most.

Table 3. Sharing Information about Green-Manure Cover Crops

	Frequency (f)	Percent (n=21)
<i>Household members who shared information</i>		
Women	14	66
Men	8	38
Children/boys	1	4.8
<i>Members of community reached most</i>		
Women	14	66
Men	8	38
Children/boys	2	9.5
<i>Types of farmers reached most</i>		
Small-scale peasants	12	57
Subsistence farmers	9	43

Discussion

There was a decline in the proportion of farmers growing lablab and crotalaria, mainly because of drought, while mucuna experienced a slight rise in the proportion of growers in season 2000A. Internal averages based on the number of farmers growing the particular technology reveal a higher level of consistent use over the seven seasons (80% for mucuna, 82% for lablab, and 62% for crotalaria), which can be attributed to the increases in soil fertility brought about by the use of the green-manure cover crops. This was also an indicator of the extent farmers integrated the green-manure cover crops into their farming systems. Bearing in mind the number of years since the trials had been completed, the present level of green-manure crop usage shows good integration, particularly of mucuna. This is apparently due to its prolific nature and easy harvesting of seed, which can also be used in the next season.

The drop in the level of lablab use is mainly due to its vulnerability to storage pests, making it difficult to save seed for the next season. Thus seed to replant it is rarely available, especially if the little seed available for planting was destroyed by drought. Crotalaria had the lowest proportion of farmers continuing to grow it and registered an increasing decline due to difficulties in getting seed, as the crop needed to stay a little longer in the field to mature. This possibly does not fit in an area with land scarcity. These trends do not imply that farmers were giving up the green-manure crops; actually, there is a clear indication of decisions to grow the crops when conditions, such as availability of seed and rain, are conducive.

Despite these trends, there were improvements in the level of soil fertility in farmers' fields at all topographical levels as perceived by the farmers after growing one, two, or all three green-manure cover crops. The positive changes in soil fertility after using the green-manure crops at all levels can be attributed to their biological nitrogen-fixing capacity, high biomass, and release of nutrients during the decomposition process (Fischler, 1997). It is observed that the soil fertility changes at the hilltop were only up to the 'fertile' level (figure 2), possibly because of the physical nature of the soils on hilltops. These soils are characterised by gravel and thin layers of top soil due to erosion, particularly if there is little soil cover. The soil at the foothills changed from poor to very fertile, probably because of the deposition of soils eroded from hill sides and the deep layer of top soil. A good proportion of farmers with fields on the flat terrain also reported a change in fertility, confirming the potential of the green manures to restore fertility of soils that are usually exhausted by over-cultivation.

The reasons farmers indicated for continuing to use the green-manure cover crops reflect their needs (poor soil fertility was a priority problem) and how the project successfully met them. Fischler (1997) reported high maize yields in on-farm trials after the use of mucuna, lablab, and crotalaria. Provision of other support technologies may also explain farmers' acceptance as they often have other needs that (if not met) may affect their acceptance of a new technology. The support technologies were many and helpful, possibly providing the participants a menu to choose from and thus appealing to their commitment to the research/development process. Use of their indigenous knowledge in some of the research went well with the concepts of participatory research where solutions must consider what the end users know and build on it, making the whole process potentially sustainable (van Veldhuizen et al., 1997). The sale of the seeds from the green-manure cover crops was a strong incentive, which, even though it was not the original goal of the project, might have motivated farmers to work hard. Farmers are always looking for sources of funds so they can meet other needs that can only be met by money. The failure to buy seed from the farmers might have been due to the lack of a fair system of collecting the seed by the local farmers' research committee, which mediated between the farmers and the research organisation. The use of the cover crops for other purposes was an additional advantage, as farmers were able to cover other areas such as lack of animal feed or vegetables for home use.

While the immediate neighbours could adopt the technology, the level of innovativeness between the participant farmers and their neighbours might explain the lack of adoption, with the participants being more innovative than their neighbours. If neighbours had a high level of innovativeness, they would have been more curious about the technologies and thus moved higher on the innovation-decision process, from knowledge or awareness to persuasion to implementation and confirmation (Rogers, 1983). It is also possible that a socio-economic gap was created between the participants and their non-participant neighbours as a result of the technologies, leading to resentment among neighbours and a reluctance to try the technologies.

The experiences of the drop-out farmers are a reflection of the consequences of an innovation, as observed by Rogers (1983). The behaviour of the leadership and the inequalities involved in the distribution of seed for the green-manure crops may be classified as an undesirable and unanticipated consequence, leading to a social gap between the drop-out farmers and the research effort. The entire milieu of reasons for dropping out of the research hinge around the way the research and development system (farmers, researchers, resources, and implied methodology) of the project operated.

Despite the lack of expansion in the use of the cover crops, the frequency of use was high (4.4 times per farmer, on average) within four years after the trials, almost one planting per year per farmer. This shows that the farmers realised the role of the technologies in restoring soil fertility, and of the potential of sustained use.

Innovations, or what Rogers (1983) calls 'reinventions,' of the green-manure technologies occurred among participant farmers. Rogers (1983) argues that reinvention occurs at the implementation of the innovation-decision stage and that it is an action taken by an adopter. This shows that adoption and, hence, integration had taken place among the 43% of the farmers who innovated with the green manures. Reinvention is regarded as beneficial to the adapters, because of the flexibility it provides in the process of adopting a technology. In addition, reinvention may encourage customisation of the innovation, making it fit local conditions, which is also part of the participatory research process. Reinvention and innovation provide self-

reliance to the users and, through the process of experimenting, may lead to a system of innovativeness (Reijntjes et al., 1992).

The management of green-manure seed seemed to take a central role, as seed was the only product of the green-manure crops from which money could be earned. Economic factors, such as the profitability of an innovation, are said to increase its adoption (Rogers, 1983). There were indications of farmers' frustration with failures to harvest lablab and crotalaria seed, which fetched more money than the prolific mucuna, and seed saving was important if the green manures were to be grown in following seasons.

The green-manure technology spread from participant farmers to other farmers in the community, justifying the role of farmer-to-farmer sharing. Indeed, farmer-to-farmer information exchange is the most common way of spreading information among farming communities (Campbell and Garforth, 2001). Ninety-five percent of the farmers indicated that they told someone else about the green-manure cover crops, making a total of 290 other farmers having been told. The mean number of those who were observed practicing for each of the green-manure crops was more than seven farmers per participant farmer. The good results in soil improvement and better crop yields after using the cover crops could have prompted this. Indeed, food security was reported to have improved among the participant farmers, prompting curiosity and the desire to try among nonparticipants (Miiri, Esilaba, and David, in progress). The role of women in disseminating the information can be explained by their important role in most agricultural activities, and also possibly due to their networks of information exchange, which function better than those of men (Campbell and Garforth, 2001). This is why more women were reached than men.

CONCLUSIONS

The green-manure cover crops—mucuna, lablab, and crotalaria—have been integrated into the farming systems of the small-scale participant farmers, as evidenced by the continued trend of using the technologies over the previous four years, the frequency of using them per field, the innovations, and the opportunities to sell the seed. Major constraints to this integration included drought, limited land size and lack of tenure, and inadequate quantities of lablab and crotalaria seed. Neighbouring farmers were aware of the green-manure cover crops but lacked practical knowledge on their use, while the organisational/leadership problems explained why some farmers dropped out of the trials. Diffusion of the technologies took place; however, this was based on the perceptions of the participant farmers and not a random community survey. Women contributed greatly to the diffusion process and reached more women.

The study reveals the need for a diffusion study, particularly exploring the roles of each gender and the effects of the technologies on household farming systems and economy. There is a need to follow up on the efforts to integrate the green-manure cover crops among participants, especially the reinventions, and to facilitate a system of self-reliance and participatory propagation of the technologies within the wider community. Mucuna and lablab should be promoted among farmers with smaller fields, while crotalaria could fit farmers with larger fields. The possibility of making crotalaria an early-maturing green-manure crop could also be explored. Finally, the availability of seed for the green-manure cover crops should be a priority, and opportunities to sell the seed should also be formalised and equitably managed. The potential for widespread integration of green-manure cover crops among small-scale farmers is very high if these factors are addressed.

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EFFET DU TRAVERTIN ET DE *TITHONIA DIVERSIFOLIA* SUR LA PRODUCTIVITÉ DU HARICOT VOLUBLE EN SOLS ACIDES DU RWANDA

Léon Nabahungu et Vicky Ruganzu

RÉSUMÉ

Le haricot est l'une des cultures principales dans l'alimentation rwandaise et représente une source importante des protéines. Cependant, il est cultivé sur des sols marginaux caractérisés par une forte acidité et une déficience en éléments nutritifs. L'objectif de l'étude était d'apporter une contribution à l'amélioration des propriétés de ces sols pour une bonne productivité des cultures. La biomasse de Tithonia diversifolia et le travertin broyé ont été utilisés l'une comme source de nutriments et l'autre comme source de calcium pour neutraliser l'acidité. Une dose de 4 t/ha de matière sèche de Tithonia diversifolia combinée à des doses croissantes de travertin a été appliquée. La culture test était la variété CAB19 du haricot volubile en alternance avec POOL9 du maïs. Les résultats ont montré un effet marquant de la combinaison de Tithonia diversifolia et du travertin. Des améliorations sensibles de rendements ont en effet été observées suite à l'application de Tithonia diversifolia combiné ou non avec du travertin : l'intensité de la réponse du travertin ou de la chaux dépend du degré d'acidité du sol.

Mots clés : Tithonia diversifolia ; travertin amendement du sol ; sols acides ; Rwanda

ABSTRACT

Common beans constitute one of Rwanda's main food crops and are a major source of protein. However, beans are cultivated on marginal soils, characterised by high acidity and nutrient deficiencies. This study aimed to restore the productivity of these soils and thereby improve bean yields by focusing on the potential of Tithonia diversifolia biomass as a source of nutrients and on the use of finely ground travertine as a source of calcite to reduce soil acidity. A dosage of 4 t/ha of dry matter of Tithonia diversifolia was combined with increasing doses of travertine and applied to two alternate test crops: the CAB19 variety of climbing beans and POOL9 variety of maize. Results showed that the interaction of Tithonia diversifolia and travertine had a very strong impact. Yields increased considerably following the application of Tithonia diversifolia, whether combined with travertine or not. The intensity of the impact of travertine and limestone applications depended on the original pH of the soil.

Keywords: Tithonia diversifolia, liming materials, soil acidity, soil fertility, Rwanda

JUSTIFICATION

Le haricot est l'une des principales cultures vivrières rwandaises. Il constitue en effet la source de protéines la plus importante du rwandais moyen. Plante considérée comme étant relativement peu exigeante en matière d'éléments nutritifs, le haricot cultivé sur des sols marginaux où la pratique de la jachère a disparu, est cependant sujet aux déficiences. Au Rwanda, environ 30 % des superficies cultivables sont constituées de sols acides dont le pH varie généralement entre 3.8 et 5.2 (Mutwewingabo, 1984). Ces sols sont classés parmi les sols tropicaux caractérisés par une déficience en phosphore et par une faible capacité d'échange cationique. Au Rwanda on trouve ces sols dans les régions agroclimatiques de la crête Congo-Nil, ou encore dans certaines zones de haute et de moyenne altitude. Là où rien n'est entrepris pour améliorer les sols, les entraves à la production du haricot n'en deviennent que d'autant plus aiguës.

Une des mesures d'amélioration possibles dans ces milieux est celle de la fertilisation par la biomasse de *Tithonia diversifolia* en combinaison avec du travertin, qui permet de corriger les défauts du pH et les carences en éléments nutritifs pour un meilleur établissement de la culture. En effet, le *Tithonia diversifolia*, espèce d'engrais vert de la famille des Astéracées (*Asteraceae*), constitue une source efficace de nutriments : la matière fraîche comporte des concentrations d'éléments nutritifs qui sont de 3.18 %, 0.23 %, 3.3 %, 3.6 % et 0.41 % pour—respectivement—l'azote, le phosphore, le potassium, le calcium et le magnésium (Bucagu,

1998 ; Jama et al, 2000 et Ruganzu, 2004). Quant au travertin brut—source importante de calcium au même titre que la chaux—il a l’avantage de pouvoir libérer les éléments graduellement. Les six gisements de travertin connus au Rwanda peuvent servir de source potentielle d’amendement calcique. La composition chimique de ces matériaux figure dans les tableaux présentés en annexe.

OBJECTIFS

Le but final de l’étude étant de contribuer à l’amélioration de la productivité des sols acides par l’utilisation du travertin combiné à *Tithonia diversifolia*, les objectifs spécifiques de l’étude s’énonçaient comme suit :

- Rendre[R.G.S.2] accessible une source de production d’intrants qui permette des amendements du sol à moindres coûts, tout en ayant un haut potentiel fertilisant ;
- Augmenter le rendement du haricot volubile.

HYPOTHÈSES

- Le travertin brut constitue une source importante de calcium au même titre que la chaux et joue le rôle d’amendement ;
- La biomasse de *Tithonia diversifolia* enfouie à l’état frais libère les éléments nutritifs dans le sol ;
- L’application du travertin combiné à la chaux améliore le rendement des cultures.

MATÉRIEL ET MÉTHODE

Commencée en 1999, l’étude comportait deux essais, avec des doses variées. Le premier essai consistait en six traitements appliqués en un seul site et le second était composé de dix traitements effectués dans deux sites. Le dispositif expérimental se composait de blocs complètement randomisés (BCR) à trois répétitions. La plante test était la variété CAB19 du haricot volubile, alternée avec la variété POOL9A du maïs pour permettre l’évaluation de l’arrière-effet. Le semis eut lieu 10 à 14 jours après application des engrais, intervalle de temps jugé comme représentant l’optimum du point de vue de la décomposition de la biomasse de *Tithonia diversifolia* enfouie dans le sol. Une seule dose de 4 t/ha de matière sèche de *Tithonia* a été utilisée et combinée avec différentes doses de travertin ou de chaux, selon les traitements.

RÉSULTATS ET DISCUSSION

Les résultats de cette étude portent sur trois saisons pour le premier essai et sur deux saisons pour le second.

Dans le premier cas, l’analyse de la variance a montré d’une part une différence significative entre traitements pour ce qui est de leur effet sur le rendement en graines du haricot et en grains du maïs pour les deux premières saisons et d’autre part, une différence non significative pour le rendement en graines du haricot en troisième saison. Le tableau 1 ci-dessous représente les résultats de cette analyse.

De façon générale, les résultats de ce tableau permettent de constater une amélioration des rendements suite à l’application

- de 2.5 t/ha du travertin plus 4 t/ha de matière sèche de *Tithonia diversifolia* (T3),
- de 2.5 t/ha de chaux plus 4 t/ha de matière sèche de *Tithonia diversifolia* (T5) et
- de 4 t/ha de matière sèche de *Tithonia diversifolia*.

Dans le cas de l’essai à dix traitements, l’analyse de la variance a montré une différence hautement significative pendant les deux saisons dans le premier site, et une différence hautement significative et très hautement significative pendant la première et la deuxième saison dans le deuxième site. Les résultats de cette analyse figurent dans le tableau 2.

Au vu des résultats de ce tableau, il y a lieu de constater que les meilleurs rendements ont été obtenus avec l’application

- de 1 t/ha de travertin plus 4 t/ha de matière sèche de *Tithonia diversifolia* (T7),
- de 1.5 t/ha de travertin plus 4 t/ha de matière sèche de *Tithonia diversifolia* (T8),
- de ½ de travertin plus 4 t/ha de matière sèche de *Tithonia diversifolia* (T6) et
- et de 4 t/ha de matière sèche de *Tithonia diversifolia*.

Tableau 1. Résultats de l'analyse de la variance des moyennes et de la comparaison multiple pour les paramètres considérés (six traitements)

Traitements	Saison	Saison	Saison
	1999 B	2000 A	2000 B
	Rendement en graines (kg/ha)		
	haricot	maïs	haricot
T0—Témoin	43,33 c	450,0 c	88,33 a
T1—2.5 t/ha de chaux	96,67 bc	948,3 bc	21,67 a
T2—2.5 t/ha de travertin	102,5 bc	472,5 c	33,33 a
T3—2.5 t/ha de travertin + 4t/ha mat. sèche de <i>Tith.div.</i>	303,30 ab	2 083,0 a	58,33 a
T4—4t/ha de matière sèche de <i>Tithonia diversifolia</i>	366,70 a	1 725,0 ab	125,00 a
T5—4t/ha de mat. sèche de <i>Tith.div.</i> + 2.5 t/ha de chaux	366,70 a	1 642,0 ab	33,33 a
Probabilité	0,0212*	0,0102*	0,5138 NS
Plus petite différence significative (0.05)	221,0	922,4	131,8
Coefficient de variation (%)	56,9	41,6	120,7

*: Différence significative

NS : Différence non significative

Tableau 2. Résultats de l'analyse de la variance des moyennes et de la comparaison multiple pour les paramètres considérés (dix traitements)

Saisons	SITE 1		SITE 2	
	Rendement (kg/ha)		Rendement (kg/ha)	
	graines de haricot	biomasse de maïs	graines de haricot	grains de maïs
	2000 A	2000 B	2000 B	2001 A
TRAITEMENTS				
T0—Témoin	733,3 d	4 571 d	456,7 ab	1 819 cde
T1—1 t/ha de chaux	1 283 cd	5 809 cd	295,0 b	1 752 de
T2—0.5 t/ha de travertin	1 300 cd	8 571 abc	209,0 b	2 038 cde
T3—1 t/ha de travertin	1 817 abc	9523 abc	247,0 b	1 523 e
T4—1.5 t/ha de travertin	1 467 bcd	7 047 bcd	333,0 b	2 381 bcd
T5—4 t/ha de mat. sèche de <i>Tithonia diversifolia</i>	2 317 ab	1 0670 ab	618,7 a	3 028 ab
T6—0.5 t/ha travertin+ 4 t/ha mat. sèche de <i>Tith. div.</i>	2 400 a	1 0290 ab	666,3 a	2 390 bcd
T7—1 t/ha travertin+ 4 t/ha mat. sèche de <i>Tith.div.</i>	2 533 a	1 1810 a	466,0 ab	2 885 ab
T8—1.5 t/ha travertin+ 4 t/ha mat. sèche de <i>Tith. div.</i>	2 267 ab	8 190 abcd	647,0 a	3 314 a
T9—1 t/ha chaux+4t/ha matière sèche de <i>Tith. div.</i>	1 917 abc	8 190 abcd	599,7 a	2 533 bc
Probabilité	0,0033**	0,0063**	0,0029**	0,0002***
Plus petite différence significative (0.05)	831,5	3336,9	241,8	655,6
Coefficient de variation (%)	26,9	23	31,1	16,2

** : Hautement significative

*** : Très hautement significative

CONCLUSIONS

Face à la dégradation progressive de son environnement agricole, le Rwanda a entrepris de multiples efforts d'amélioration des sols en explorant différentes solutions possibles. Une des études visant à apporter une contribution à la productivité des sols acides a porté sur l'utilisation du travertin combinée à celle du *Tithonia diversifolia*. Les résultats de cette étude, qui fut réalisée en menant deux essais comprenant différents traitements, ont confirmé un effet très marquant du travertin combiné à la biomasse de *Tithonia*

diversifolia. Cependant, l'on a observé également des améliorations du rendement suite à l'application d'une combinaison de chaux et de *Tithonia* ou bien de *Tithonia* seulement. Par ailleurs, l'intensité de la réponse soit du travertin, soit de la chaux combinée à *Tithonia* dépend du degré d'acidité du sol cultivé. Ceci pourrait expliquer les faibles rendements observés dans le cadre du premier essai où le sol variait entre acide et très acide (pH 3.8–4.1), par rapport à ceux du second où le sol était soit acide (pH 4.4–4.9), soit légèrement acide (pH 5.1–5.4). Il a été également démontré que les effets des efforts d'amélioration peuvent être manifestes jusqu'à la deuxième ou même la troisième saison.

FACILITÉS DE TRANSFERT

L'adoption de cette nouvelle technologie dans les milieux paysans est favorisée par la disponibilité des matériaux nécessaires. Le travertin brut est moins cher que la chaux et sa production ne nécessite ni énergie, ni technologie spéciales. Comme le travertin libère graduellement les éléments qu'il apporte, l'arrière-effet positif de cet amendement calcique est encore manifeste à la deuxième ou même à la troisième saison. Quant à la présence au Rwanda de *Tithonia diversifolia* : c'est une plante spontanée que l'on trouve dans presque toutes les zones agrobioclimatiques. La biomasse est enfouie dans le sol après les travaux de labour et se décompose en 10 à 14 jours : pendant cette période de temps qui précède la mise en place de la culture, les éléments nutritifs enrichissent le sol. Ainsi, la technologie est d'application facile et moins coûteuse que l'apport d'autres engrais minéraux.

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ANNEXES

Tableau 3. Composition chimique des travertins utilisés comme amendements calciques au Rwanda

Gisements	CaO (%)	CaCO ₃ (%)	MgO (%)	pH (H ₂ O)	pH (KCl)	ΔpH
TRA	38,5	68,5	7,3	8,6	8,4	-0,2
TME	35,8	63,7	3,8	8,1	6,9	-1,2
TMI	28,5	50,7	1,8	8,4	8,0	-0,4
TMO	40,6	72,3	5,5	8,4	8,2	-0,2
TRO	31,5	56,1	2,3	7,6	6,9	-0,7
TRMA	—	—	—	—	—	—

Légende:

- TME : travertin de Mpenge (Ruhengeri)
 TMI : travertin de Mpatsi (Kibuye)
 TMO : travertin de Masangano (Ruhengeri)
 TRA : travertin de Rwaza (Ruhengeri)
 TRO : travertin de Ruhundo (Kibuye)
 TRMA : travertin de Mashyuza (Cyangugu)

Tableau 4. Propriétés chimiques des sites avant installation des essais : Essai 1

Traitements	pH (H ₂ O)*	pH(KCl)	ΔpH
T0-Témoin	3,8	3,5	-0,3
T1-2.5 t/ha de chaux	3,9	3,5	-0,4
T2-2.5 t/ha de travertin	3,8	3,5	-0,3
T3-2.5 t/ha de travertin + 4 t/ha mat. sèche de <i>Tith.div.</i>	4,1	3,6	-0,5
T4-4 t/ha de matière sèche de <i>Tithonia diversifolia</i>	4,1	3,6	-0,5
T5-4 t/ha de mat. sèche de <i>Tith.div.</i> + 2.5 t/ha de chaux	3,9	3,4	-0,5
Variation	3,8-4,1	3,4-3,6	

*Le sol de ce site a un pH qui varie de 3,8 à 4,1, ce qui correspond à un sol acide à très acide.

Tableau 5. Propriétés chimiques des sites avant installation des essais : Essai 2

Traitements*	Site 1			Site 2		
	pH (H ₂ O)**	pH (KCl)	ΔpH	pH (H ₂ O)	pH (KCl)	ΔpH
T0	4,4	3,9	-0,5	5,4	4,6	-0,8
T1	4,5	4,2	-0,3	5,3	4,6	-0,7
T2	4,7	4,2	-0,5	5,1	4,4	-0,7
T3	4,8	4,3	-0,5	5,2	4,5	-0,7
T4	4,9	4,4	-0,5	5,2	4,5	-0,7
T5	4,7	4,1	-0,6	5,3	4,6	-0,7
T6	4,4	4,1	-0,3	5,4	4,6	-0,8
T7	4,8	4,3	-0,5	5,1	4,2	-0,9
T8	4,6	4,2	-0,4	5,2	4,5	-0,7
T9	4,4	4,1	-0,3	5,4	4,6	-0,8
Variation	4,4-4,9	3,9-4,4		5,1-5,4	4,2-4,6	

* Description des traitements :

T0 : témoin

T1 : 1 t/ha de chaux

T2 : ½ t/ha de travertin

T3 : 1 t/ha de travertin

T4 : 1.5 t/ha de travertin

T5 : 4 t/ha de matière sèche de *Tithonia diversifolia*

T6 : ½ t/ha travertin+ 4 t/ha matière sèche de *Tithonia diversifolia*

T7 : 1 t/ha travertin+ 4 t/ha matière sèche de *Tithonia diversifolia*

T8 : 1.5 t/ha travertin+ 4 t/ha matière sèche de *Tithonia diversifolia*

T9 : 1 t/ha chaux+4 t/ha matière sèche de *Tithonia diversifolia*.

Le pH varie de 4,4 à 4,9 dans le site et de 5,1 à 5,4 dans le site 2, ce qui correspond respectivement à un sol acide et un sol légèrement acide.

L'EFFICACITE DE *TITHONIA DIVERSIFOLIA* EN TANT QU'AMENDEMENT EDAPHIQUE POUR LA CULTURE DU HARICOT COMMUN (*PHASEOLUS VULGARIS* L.)

Ngongo Mulangwa

RÉSUMÉ

Une série d'études conduites dans la province congolaise du Sud-Kivu avait pour objet d'évaluer les potentialités offertes par les biomasses de Tithonia diversifolia en tant qu'amendement organique pour la culture du haricot commun. À l'issue de l'estimation des biomasses de Tithonia produites sur les clôtures des champs, il s'est avéré que les quantités produites, à savoir en moyenne 600 kg sur un champ de 1 ha, varient entre autres en fonction du niveau de fertilité du sol ainsi que de la technique de taille des arbustes (fréquence, hauteur de taille, etc...). Cette quantité est insuffisante, la courbe des réponses du haricot aux dites biomasses ayant montré que la dose requise pour un effet palpable sur le rendement du haricot peut dépasser 6 t/ha dans les conditions des sols pauvres comme ceux des terrains dominés par Pennisetum polystachia. Rien qu'avec les biomasses de Tithonia, des accroissements spectaculaires de rendement du haricot (de l'ordre de 150 % du témoin sans fumure) peuvent être obtenus sur ces sols. Toutefois, là où la déficience en phosphore constitue la principale limitation, la combinaison des biomasses avec les engrais minéraux s'avère indispensable pour permettre au haricot de mieux exprimer son potentiel de production. Quant aux techniques d'épandage, nos résultats montrent que les meilleurs effets de ces biomasses de Tithonia s'obtiennent quand celles-ci sont incorporées au sol et cela deux à cinq jours avant le semis du haricot.

ABSTRACT

In an effort to improve soil fertility for improved bean productivity, a series of studies were carried out in Southern Kivu to evaluate the effectiveness of applying biomass of Tithonia diversifolia as an enriching agent. Green-leaf mass cut from Tithonia shrubs grown as hedges around fields were weighed; on average, a one-hectare field produced 600 kg of Tithonia—the amounts harvested varying with the level of soil fertility and the pruning technique used (frequency, height of clipping, etc.) This amount is insufficient: the dose-response curve for beans shows that over 6 t/ha of Tithonia biomass may be required in order to have a measurable effect on bean yields in conditions involving poor soils such as those dominated by Pennisetum polystachia. Yet results can be spectacular: yield increases of up to 150% have been registered following the use of Tithonia alone, i.e., without the addition of mineral fertilisers. Nevertheless, where beans are cultivated on poor soils, especially those where the main constraint is a phosphorus deficiency, it is necessary to combine the Tithonia biomass with mineral fertilisers in order to more fully realise the crop's production potential. With regard to spreading techniques, our findings indicate that the best results are achieved where the Tithonia biomass has been incorporated by burying it in the ground two to five days before sowing the beans.

INTRODUCTION

Des études relativement récentes sur la culture du haricot commun (*Phaseolus vulgaris* L.) en Afrique, portant à la fois sur le continent en général (Wortmann et al., 1999) et sur la région du Sud-Kivu en particulier (Musungayi et al., 1990; Ngongo et al., 1995) ont révélé que dans cette dernière, la faible fertilité des sols est un des principaux facteurs entravant une bonne productivité du haricot. Il est bien connu que la fumure, aussi bien minérale qu'organique, permet d'améliorer les sols et, bien que faiblement documentée, la réponse favorable du haricot aux amendements édaphiques a été établie, non seulement dans la région des Grands Lacs en général (Sebahutu, 1988) mais aussi dans le Sud-Kivu (Ngongo et Lunze, 2000). Cependant, cette réponse s'avère souvent faible par rapport à celle d'autres cultures dont le maïs et la pomme de terre, et là où il faut avoir recours à des engrais minéraux onéreux, elle n'offre pas une solution économique.

Ainsi, c'est l'amendement organique qui demeure l'intrant le plus accessible au petit fermier même si là aussi, de grandes difficultés s'opposent à son utilisation : d'une part l'ignorance des techniques de gestion efficaces et d'autre part la faible disponibilité d'engrais organiques abordables. En effet, comme l'affirme Singh (1988), il est rare qu'un fermier à faible revenu dispose des quantités très élevées d'engrais organiques requises pour en assurer l'effet considérable voulu. Souvent l'application du compost et du fumier animal se heurte à l'insuffisance des matières premières requises pour leur fabrication et se limite de ce fait, aux activités de jardinage et pépinière. Même là où les matières premières sont disponibles, le problème du transport peut freiner l'adoption de la fumure par le compost et le fumier animal. Par ailleurs, l'utilisation de l'engrais vert est encore restreinte, notamment par des problèmes de mentalités.

Il faut donc recourir aux amendements organiques plus disponibles en milieu réel. La présente étude porte sur les biomasses de *Tithonia diversifolia*, un arbuste généralement utilisé comme clôture des champs et parcelles dans le Sud-Kivu, dont elle évalue la capacité d'améliorer la fertilité des sols et la productivité du haricot. Des recherches menées sous d'autres ciels ont permis de signaler les effets spectaculaires du *Tithonia* sur le rendement du maïs (Gachengo, 1996) et de certains légumes (ICRAF, 1997). Rares sont cependant les études qui ont examiné l'effet de ces biomasses sur la culture du haricot.

Outre leur disponibilité relativement grande par suite de leur production autour des champs, les biomasses de *Tithonia* se caractérisent—selon Buresh and Tian (1998)—par une vitesse de décomposition qui résulte, d'après Palm *et al.* (1997), de leur bonne composition en lignines, polyphénols et azotes (N). Par ailleurs, comparativement à d'autres amendements organiques, dont les doses requises varient entre 10 et 40 t/ha (dans notre région d'étude), les biomasses de *Tithonia* peuvent être efficacement utilisées à des doses nettement moins importantes, grâce la teneur relativement élevée en macroéléments. Nagarajah et Nizar (1982) rapportent une teneur en N et K atteignant 5,5 % ainsi qu'une teneur en P de 0,5 % exprimées par rapport à la matière sèche.

OBJECTIF

L'objectif de l'étude était d'évaluer les potentialités réelles et les limitations des biomasses de *Tithonia* en tant qu'amendement du sol pour la culture du haricot. Différents essais ont permis d'explorer comment appliquer cet amendement avec plus de facilité et d'efficacité dans les conditions réelles du fermier. Car, selon l'affirmation de Duncan (1974), toute société devrait axer son développement sur l'utilisation optimale des ressources qu'elle a en abondance.

MATERIEL ET METHODE

L'étude se composait de quatre investigations, à savoir :

- Quantification des biomasses de *Tithonia* produites sur les clôtures des champs.
- Courbe des réponses du haricot aux biomasses de *Tithonia*, à différents niveaux de fertilité du sol tels que déterminés par la prédominance sur le terrain d'une des trois espèces végétales suivantes :

Pennisetum polystachia, *Bidens pilosa* ou *Galinsoga parviflora*. D'après Ngongo et Lunze (2000), ces plantes constituent des indices fiables de fertilité respectivement faible, moyenne ou élevée. Le recours à ce critère dans la présente étude se justifie par la nécessité de faciliter l'application des résultats par les paysans n'ayant pas accès aux analyses de laboratoire.

- Études de différentes techniques d'épandage des biomasses de *Tithonia* dans la culture de haricot.
- Combinaison des biomasses de *Tithonia* avec les engrais minéraux.

Ces investigations ont été conduites dans la partie nord du territoire rural de Kabare, dans la province du Sud-Kivu, à l'est de la République Démocratique du Congo. D'après Pécrot *et al.* (1962), les sols de la région font partie de la série Bô-S21 classées comme ferrisols humifères, rouges et argileux sur basalte. Dans la « U.S. Soil Taxonomy », ils correspondraient à « Oxic Rhodic Paleudult ».

Le régime pluviométrique est bimodal, la première saison (A) s'étendant de septembre à novembre et la deuxième (B) de mars à mai. La moyenne annuelle des précipitations calculée sur une période de 20 ans s'élève à 1 572 mm (Crabbe et Totiwe, 1979). Les données climatiques se rapportant à la durée de l'étude—à savoir de 1998 à 2000—indiquent un déficit de pluies au cours de la saison B de 1998 (de mars à mai) : 266,5 mm seulement, contre 491 mm en 1999 et 306,4 mm en 2000.

Quantification des biomasses de *Tithonia* produites sur les clôtures des champs des paysans

L'efficacité d'un amendement organique se mesure non seulement par son effet sur le rendement mais aussi par la disponibilité des matières organiques à épandre. Dans le but d'estimer les quantités de biomasses de *Tithonia* produites dans le système paysan de clôture des champs, nous avons effectué la pesée des biomasses coupées sur les haies de *Tithonia* entourant 20 champs en milieu rural dans le territoire rural de Kabare.

Réponse du haricot à des doses croissantes de biomasses de *Tithonia diversifolia* enfouies dans les sols de champs où dominant *Pennisetum polystachia*, *Bidens pilosa* et *Galinsoga parviflora*

Cette étude a été conduite en milieu rural, à Bushumba. Les terrains d'essais se caractérisaient par une présence dominante (70 % au moins, selon l'échelle de Braun-Blanquet, 1956) de trois espèces végétales spontanées—à savoir *Pennisetum polystachia*, *Bidens pilosa* et *Gallinsoga parviflora*—considérées dans la région comme indice respectivement d'infertilité, de fertilité moyenne et de fertilité élevée des sols. Sur chaque lopin de terre dominé par l'une de ces herbes, quatre doses (de 0, 2, 4 et 6 t/ha) de biomasses de *Tithonia* préalablement coupées furent enfouies dans le sol quatre jours avant le semis de la variété de haricot Kirundo diffusée dans la région. Le dispositif expérimental était celui en split-plot, avec subdivision de parcelles : la parcelle principale indiquait le niveau de fertilité (déterminé par la plante indicatrice) et les doses de biomasses de *Tithonia* étaient appliquées aux 4 parcelles subdivisées. Ainsi on put comparer 12 objets au total, en observant l'effet sur le rendement du haricot.

Techniques d'épandage au sol des biomasses de *Tithonia*

Cette étude fut menée à Mulungu (à 1 650 m d'altitude). Le sol se caractérisait essentiellement par une carence en N et P tel que l'on peut bien le noter sur le tableau 1 ci-après. Le précédent cultural était composé d'une jachère dominée par *Bidens pilosa*.

Tableau 1. Quelques propriétés chimiques du sol du site d'essai

pH (1:2,5)		% C	% N	% C/N	P(Brayl) (mg/kg)	Ca (méq/100g)	Mg (méq/100g)
H ₂ O	KCl						
5,80	4,80	1,62	0,15	10,80	5,70	12,90	2,50

Conduit dans un dispositif à blocs complètement randomisés et ce en deux saisons culturales (2000A et 2000B), cet essai a mis en comparaison six techniques d'épandage des biomasses de *Tithonia* au sol reprises ci-dessous :

1. Témoins sans amendement (T1)
2. 6 t/ha des biomasses de *Tithonia* enfouies dans le sol le jour même du semis du haricot (T2)
3. 6 t/ha des biomasses de *Tithonia* enfouies dans le sol 7 jours avant le semis (T3)
4. 6 t/ha des biomasses de *Tithonia* enfouies 4 jours avant le semis (T4)
5. 6 t/ha des biomasses de *Tithonia* enfouies dans le sol 2 jours avant le semis (T5)
6. 6 t/ha des biomasses de *Tithonia* épandues en surface 7 jours avant semis du haricot et enfouies dans le sol le jour même du semis du haricot.

Il convient de signaler que la dose de 6 t/ha avait été retenue pour avoir donné la meilleure réponse du haricot dans une étude antérieure. Après leur découpage, les biomasses furent épandues sur des parcelles élémentaires de 11,2 m². L'enfouissement dans le sol, pour les objets concernés, fut effectué au moyen d'un trident. L'évaluation de ces traitements a porté sur le rendement du haricot grain à la récolte.

Combinaison des biomasses de *Tithonia* avec l'engrais minéral

Comme la précédente étude celle-ci avait été conduite à Mulungu, mais avait évalué différentes combinaisons des biomasses avec un engrais minéral, dans le but de pallier la difficulté d'accès des fermiers aux engrais minéraux et de remédier à la carence en certains macroéléments des amendements organiques.

Quatre doses d'un engrais chimique équivalentes à 0, 20, 40, 60 kg/ha de N, P, et K ont été combinées à une dose unique de 4 t/ha de biomasses de *Tithonia* faisant, avec le témoin absolu (sans fumure), 6 traitements ci-dessous décrits :

1. Témoin (F1)
2. 4 t/ha des biomasses de *Tithonia* + 0 kg/ha N, P, K (F2)
3. 4 t/ha des biomasses de *Tithonia* + 20 kg/ha N, P, K (F3)
4. 4 t/ha des biomasses de *Tithonia* + 40 kg/ha N, P, K (F4)
5. 4 t/ha des biomasses de *Tithonia* + 60 kg/ha N, P, K (F5)
6. 60 kg/ha N, P, K. (F6)

N, P, et K ont été appliqués sous forme de l'engrais composé N₁₇P₁₇K₁₇, disponible sur le marché local. Toutes les formules de fumure avaient été appliquées au sol 7 jours avant le semis du haricot, dans un dispositif à blocs complètement randomisés, sur des parcelles élémentaires de 1,2 m². L'évaluation de l'effet des traitements eut lieu à la récolte, en comparant le rendement du haricot grain. L'analyse combinée des données de deux saisons culturales s'est faite à l'aide du logiciel MSTATC (Nissen et al., 1985).

RESULTATS ET DISCUSSIONS

Quantification de la production de biomasses de *Tithonia*

Les observations relatives à l'analyse portant sur deux saisons culturales révèlent que les quantités de biomasses produites sur les clôtures des champs varient considérablement (allant du simple au double) en fonction du niveau de fertilité du sol, la production étant plus élevée sur un sol fertile. Par ailleurs, la technique de taille des arbustes de *Tithonia* (fréquence, hauteur de taille, etc.) semble influencer elle aussi sur la production des biomasses. Dans ce système paysan, en une coupe, on obtient en moyenne 600 kg de biomasses de *Tithonia* sur la clôture d'un champ de 1 ha.

Réponse du haricot aux doses croissantes de biomasses de *Tithonia*

Le tableau 2 présente les résultats de cette investigation. La comparaison des différents rendements moyens obtenus selon ce que le sol portait l'une ou l'autre des trois espèces d'herbes indicatrices permet de mieux faire ressortir l'effet de l'interaction du *Tithonia* et du niveau de fertilité du sol.

Tableau 2. Effet des biomasses de *Tithonia diversifolia* comme amendement édaphique sur le rendement du haricot commun dans des conditions variables de fertilité indiquées par la dominance du terrain par *Pennisetum polystachia*, *Bidens pilosa* et *Gallinsoga parviflora*, au Sud-Kivu, RDC

Doses des biomasses de <i>Tithonia diversifolia</i> (t/ha)	Rendement du haricot (kg/ha)		
	Sol à <i>Pennisetum polystachia</i>	Sol à <i>Bidens pilosa</i>	Sol à <i>Gallinsoga parviflora</i>
0	230 d*	949 c	1 775 b
2	533 c	1 358 b	1 841 ab
4	838 b	1 788 a	1 901 b
6	1 565 a	1 788 a	2 034 a
C.V. (%)	39,2	39,2	39,2
Moyenne (kg/ha)	791,5	1 470,7	1 887,7

*Les moyennes suivies d'au moins une lettre semblable par (colonne) ne diffèrent pas statistiquement au point de probabilité 5 %.

D'après Ngongo et Lunze (2000), la prédominance sur un terrain de l'une ou l'autre des espèces *Pennisetum polystachia*, *Bidens pilosa* ou *Gallinsoga parviflora* est un indice généralement fiable d'un niveau de fertilité : fertilité respectivement faible, moyenne et élevée. Il se dégage de l'examen du tableau 1 que les biomasses ont un effet significatif sur le rendement du haricot à tous ces différents niveaux de fertilité. Ceci

prouve que, quelque soit son niveau global de productivité, chacun de ces sols accuse une déficience susceptible d'être comblée par les nutriments apportés par les biomasses de *Tithonia*.

L'augmentation du rendement se montre plus net sur le sol le plus pauvre de la série, à savoir celui d'un terrain dominé par *Pennisetum polystachia*. Les courbes de réponse d'allure linéaire présentées à la figure 1 illustrent mieux cette réalité et montrent que le rendement du haricot continuait à augmenter, jusqu'à la dose de 6 t/ha des biomasses de *Tithonia diversifolia*, qui correspond à un apport au sol de 54, 5,4 et 54 kg/ha respectivement de N, P et K (considérant les teneurs de 3 %, 0,3 % et 3 % de N, P, K dans les biomasses rapportées par la littérature). Cela laisse penser que le rendement maximal n'était pas encore atteint, sans doute en raison de la composition relativement faible des biomasses de *Tithonia diversifolia* en P (0,3 %) et épandues sur un sol qui, selon les résultats de Ngongo et Lunze (2000), se caractérise par une carence prononcée en P assimilable. Il est intéressant de noter que l'application de 6 t/ha des biomasses a permis un accroissement spectaculaire de rendement de 580 % du témoin sur ce sol. Sur le sol à niveau intermédiaire de fertilité (dominé par *Bidens pilosa*), la courbe des réponses atteint un palier à la dose de 4 t/ha avec un rendement supérieur (de 223 kg/ha) à celui induit par la dose de 6 t/ha des biomasses sur un lopin dominé par *Pennisetum polystachia*. Ceci indique que le sol à *Bidens pilosa* aurait un potentiel de production plus élevé que celui des lopins dominés par *Pennisetum*. La plus-value de rendement du haricot sur ce sol, quoique inférieure à celle enregistrée sur les parcelles dominées par *Pennisetum* (580 %), a été suffisamment élevée (88% du témoin) pour justifier l'épandage des biomasses de *Tithonia*. Comparée à 6 t/ha, la dose de 4 t/ha des biomasses passe pour la plus économique sur ce sol à niveau moyen de fertilité pour la culture du haricot. Par contre, sur une parcelle dominée par *Gallinsoga parviflora*, les biomasses de *Tithonia* n'ont produit qu'un effet minime, soit un accroissement de rendement de 14 % seulement du témoin contre 580 % et 88 % respectivement sur un terrain à *Pennisetum* et à *Bidens*. Le rendement suffisamment élevé du haricot sur ce sol sans fumure (à savoir 1 775 kg/ha) prouve que ce sol est d'un bon niveau de fertilité naturelle et explique la faiblesse des effets des biomasses.

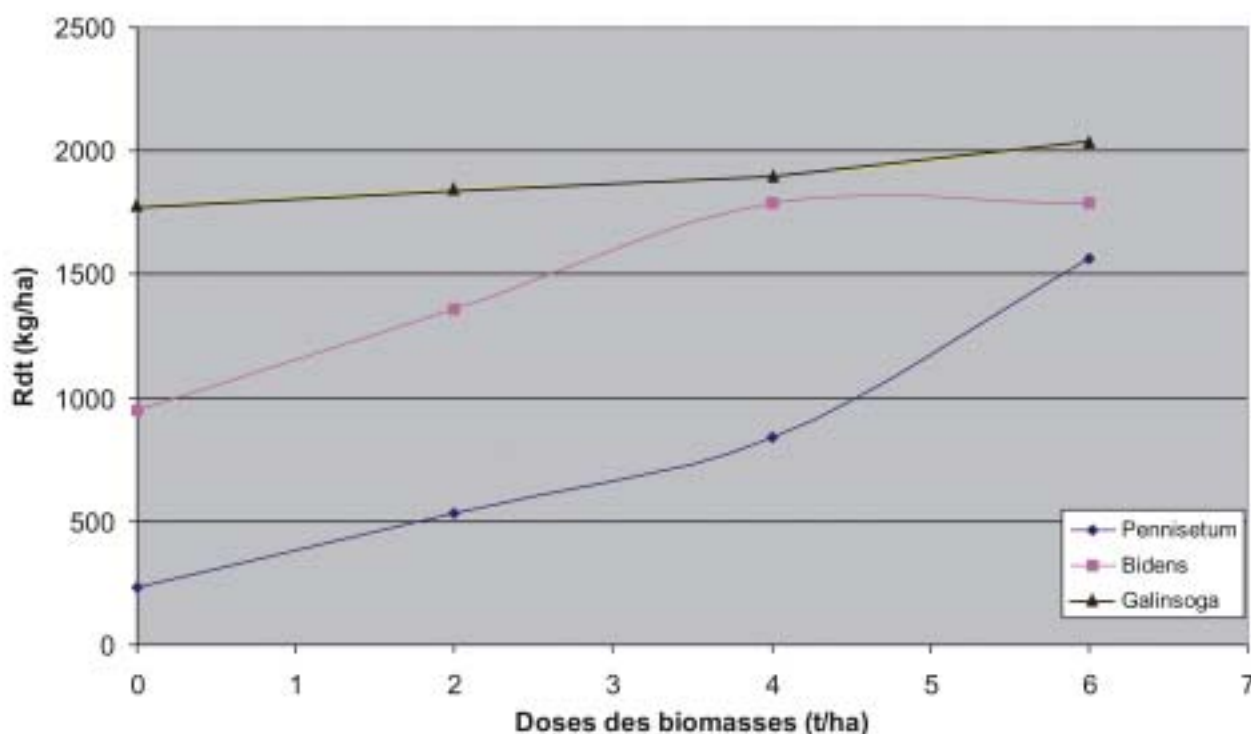


Figure 1. Evolution du rendement du haricot en fonction des doses des biomasses de *Tithonia diversifolia* sur des sols dominés par différentes herbes indicatrices de fertilité

Techniques d'épandage des biomasses de *Tithonia* au sol pour la culture du haricot

Les résultats de l'étude résumés au tableau 3 montrent que les saisons exercent une influence significative sur le rendement du haricot. Globalement, le rendement de cette culture en saison A (grande saison de pluie)

dépasse celui de la saison B d'environ 22 %. Ceci souligne l'importance de la pluviométrie sur la physiologie et la productivité des plantes cultivées ; selon Morel (1991), ces dernières réagissent au déficit hydrique par une production minimale. Cette influence s'explique aussi par le rôle capital joué par l'eau dans l'assimilation des nutriments apportés par les amendements organiques : en effet, comme l'indiquent Flaig et al. (1977) ; Musa (1975) et Anonyme (1965), ces nutriments ne sont disponibles aux plantes qu'après la minéralisation des amendements organiques. Il convient toutefois de faire remarquer qu'il n'y a pas eu d'interaction significative entre la saison et la technique d'épandage : l'impact d'une méthode d'épandage donnée ne varie pas en fonction de la saison.

Tableau 3. Effet de différentes techniques d'épandage des biomasses de *Tithonia diversifolia* sur le rendement du haricot en deux saisons culturales (2000 A/B), à Mulungu, RDC

Techniques d'épandage des biomasses de <i>Tithonia</i>	Rendement du haricot (kg/ha)	
	2000 A	2000 B
0 t/ha (témoin)	563 fg*	375 g
6 t/ha enfouies le jour du semis du haricot	1 253 bc	985 cde
6 t/ha enfouies 7 jours avant semis du haricot	1 327 bc	1 174 bcd
6 t/ha enfouies 2 jours avant semis du haricot	1 703 a	1 273 bc
6 t/ha en surface, enfouissement au semis du haricot	776 ef	854 def
C.V. (%)	19,45	19,45
Moyenne (kg/ha)	1 174,17	961,00

*Les chiffres suivis d'au moins une lettre semblable ne diffèrent pas statistiquement au point de probabilité 5 %.

L'examen du tableau ci-dessus révèle que tous les traitements comprenant l'amendement du sol par les biomasses de *Tithonia* étaient significativement supérieurs au témoin sans amendement. En moyenne, l'accroissement de rendement obtenu avec l'apport de cet amendement était de 13 % en saison 2000 A et 187 % en 2000 B, ce indépendamment de la technique d'épandage par rapport au témoin. Cette influence significative des biomasses de *Tithonia* s'explique essentiellement, outre leurs effets sur les propriétés physiques du sol, par leur apport non négligeable d'azote (environ 54 kg/ha) sur un sol déficient en ce macroélément. En effet, selon Thung (1991), le niveau critique de N dans le sol pour le haricot se situe à 0,2 %. Dans une étude antérieure portant sur l'évaluation des émondes de quelques espèces arbustives comme source d'azote, Gutteridge (1992) avait également constaté que l'incorporation des biomasses donnait de meilleurs résultats que l'épandage en surface. Cela s'explique, selon Kang and Mulongoy (1992) par la simple raison que l'incorporation présente l'avantage de réduire les pertes de l'azote par volatilisation. De même, l'incorporation est reconnue comme étant plus efficace, eu égard à une meilleure minéralisation de l'azote organique (Wilson et al., 1986). Nos résultats concordent avec ceux de Gutteridge évoqués ci-haut. En effet, quelque fût la saison—2000 A ou 2000 B—nous remarquons que l'épandage de 6 t/ha des biomasses en surface ne produisit pas d'effet significatif sur le rendement et ne différa pratiquement pas du témoin sans fumure. Il faut toutefois signaler que la technique d'épandage par enfouissement, quoique plus performante, pourrait s'avérer moins économique vu l'importance de la main-d'oeuvre requise pour la pratiquer.

Combinaison des biomasses de *Tithonia* à l'engrais minéral ($N_{17}P_{17}K_{17}$)

Le tableau 4 présente les rendements du haricot suite à l'application de différentes formules de fumure. On observe que, sur un même site, le rendement du haricot en saison A fut pratiquement le double de celui obtenu en saison B. La saison a une fois de plus exercé une influence remarquable tant sur le rendement du haricot que sur la réponse du haricot à la fertilisation. Or, comme les données pluviométriques relatives aux deux saisons culturales ne diffèrent pas sensiblement—étant de 499,1 mm (saison 1999 A) et de 491,0 mm (en 1999 B)—il y a lieu de supposer que l'influence de la saison est liée à des éléments du climat autres que la hauteur des pluies.

La réponse positive du haricot à la fumure est visible au cours des deux saisons, mais surtout en 1999 A.

S'agissant des formules de fumure, la comparaison des moyennes de rendement à l'issue d'une analyse combinée des données des deux campagnes culturales révèle une influence significative de la fumure sur le rendement du haricot. Cependant, si toutes les formules de fumure se sont montrées supérieures au témoin sans amendement, aucune différence significative n'a été enregistrée entre elles, et cela est vrai pour les deux saisons culturales. Mais, à la différence de la saison B, en saison A (grande saison de pluie), le traitement

Tableau 4. Effet des biomasses des biomasses de *Tithonia diversifolia* combinées (ou non) avec un engrais minéral (NPK), sur le rendement du haricot, à Mulungu-RDC

Formules de fumure	Rendement du haricot (kg/ha)	
	Saison 1999 A	Saison 1999 B
Témoin (sans fumure)	660 cd	551 d
4 t/ha <i>Tithonia</i> seules	1 755 a	1 132 cd
4 t/ha <i>Tithonia</i> + 20 kg/ha NPK	2 201 ab	1 341 bc
4 t/ha <i>Tithonia</i> + 40 kg/ha NPK	2 296 a	1 313 c
4 t/ha <i>Tithonia</i> + 60 kg/ha NPK	2 390 a	1 402 bc
60 kg/ha NPK seuls	2 321 a	1 405 bc
C.V. (%)	23,41	32,41
Moyenne (Kg)	2004,83	1190,67

Les moyennes suivies d'au moins une lettre semblable ne diffèrent pas statistiquement au point de probabilité 5 %.

4 t/ha de *Tithonia* sans engrais minéral a donné un rendement significativement plus élevé (de 65 %) par rapport au rendement du témoin ; il est légèrement inférieur au rendement obtenu suite à l'application des formules combinant le *Tithonia* à l'engrais minéral. En saison B, la fumure tant minérale qu'organique (et tant à l'état pur que les différentes combinaisons décrites) n'a pas eu un effet significatif. En zone tropicale, l'avantage de l'application combinée de l'engrais minéral et des amendements organiques, par rapport à l'application pure de l'une ou de l'autre forme de fumure, s'explique entre autres par la prédominance de minéraux kaolinitiques en cette zone qui ne possèdent qu'un faible pouvoir adsorbant et n'agissent bien qu'en combinaison avec l'humus (Agboola et al., 1974). Nombre d'études antérieures, dont celles de Flaig et al. (1977) et de Mayona and Kamasho (1998), démontrent la supériorité de la combinaison des engrais organiques et minéraux par rapport à leurs effets individuels. Pour le cas précis de *Tithonia*, la combinaison avec le NPK dans notre essai permet de combler son déficit en P. L'absence d'une différence significative entre l'effet de *Tithonia* seul et de sa combinaison avec l'engrais NPK est compréhensible dans la mesure où l'on a reconnu que la carence principale des sols du site de l'expérimentation est la carence en azote et non pas en phosphore. L'effet, sur le rendement du haricot, de l'application des seuls 60 kg/ha de N, P, et K (sous forme de l'engrais N₁₇P₁₇K₁₇) a été supérieur (de 273 kg/ha en saison B et de 566 kg/ha en saison A) à l'effet obtenu suite à l'application des 4 t/ha de *Tithonia* sans plus—bien qu'en saison B la différence ne soit pas statistiquement significative.

Par ailleurs, on constate, et ce particulièrement en saison A, qu'il n'y a pas de différence significative entre le résultat de la formule 4 t/ha de *Tithonia* seul et les formules combinées de la dose de *Tithonia* avec les doses de 20, 40 ou 60 kg/ha d'engrais NPK.

Au vu de ces résultats, on peut affirmer que dans des conditions édaphiques caractérisées essentiellement par la carence en N, l'amendement par les biomasses de *Tithonia* peut améliorer le sol et le rendement du haricot aussi efficacement que l'engrais minéral.

CONCLUSIONS

Au terme de trois ans d'expérimentation dans le Sud-Kivu, nous pouvons affirmer que les biomasses de *Tithonia diversifolia*, arbuste bien connue et disponible en milieu rural dans la région étudiée, constituent une alternative efficace pour la fertilisation du haricot, culture qui ne bénéficie que très rarement de la fumure.

Nos investigations ont montré qu'à l'instar d'autres amendements organiques, le recours à *Tithonia* soulève des problèmes de transport et de main d'œuvre supplémentaire eu égard aux quantités relativement grandes (6 t/ha) requises pour un effet significatif. Il convient toutefois de faire remarquer que, par comparaison à d'autres amendements (compost, fumier de ferme, etc.) connus dans la région d'étude (Sud-Kivu), ces dernières contraintes sont atténuées pour les biomasses de *Tithonia diversifolia* car elles ne proviennent pas exclusivement de l'extérieur de l'exploitation paysanne. Des accroissements de rendement notables sur la culture du haricot ne sont obtenus qu'avec un minimum de 6 t/ha de biomasses de *Tithonia*, ce qui ne peut être obtenu dans le dispositif paysan, c'est-à-dire en produisant les biomasses sur les haies de *Tithonia* utilisées comme clôtures des champs. D'après nos estimations, l'on ne peut récolter que 600 kg des dites biomasses en une coupe sur la clôture d'un champ d'une superficie de 1 ha. Vu que cela ne représente que

10 % de la quantité requise (au moins 6 t/ha) pour une productivité acceptable du haricot, il s'avère nécessaire d'importer des biomasses de *Tithonia* de l'extérieur de l'exploitation. Par ailleurs, sur un sol très dégradé, l'amendement par les biomasses de *Tithonia diversifolia* ne suffit pas et doit être associé à un supplément de nutriments sous forme minérale. Les résultats de la présente étude montrent également que, pour mieux valoriser les effets des biomasses de *Tithonia* sur le rendement du haricot, il faut les enfouir au sol, au moins deux jours et au plus cinq jours avant la date du semis du haricot. Pour mieux exploiter les potentialités de cette ressource accessible à tous, il y a lieu d'étudier, dans diverses conditions édapho-climatiques, des dispositifs qui permettraient d'augmenter la production des biomasses autour du champ en vue de minimiser le besoin d'importation des biomasses ainsi que les difficultés de leur transport.

Une telle étude permettra également d'évaluer l'adaptation du haricot au dispositif efficace de production de ces biomasses. De même, une analyse économique s'avère indispensable dans le but de proposer aux fermiers des doses et techniques de gestion (épandage et autres) plus rentables de biomasses en rapport avec différents systèmes de culture pratiqués dans les exploitations paysannes.

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PHYSIOLOGICAL INDICATORS OF DROUGHT RESISTANCE IN COMMON BEANS (*PHASEOLUS VULGARIS*)

Tilahun Amede

ABSTRACT

Drought is becoming the most important abiotic stress affecting the productivity of beans in many parts of the world, aggravated by increasing land degradation, unpredictable rainfall patterns, and low water-holding capacity in the soil. Despite the alarming demand for drought-resistant cultivars, breeders have been slow to achieve this goal due to the challenge of identifying traits that reflect true drought resistance. There are four different scenarios for drought in Sub-Saharan Africa: full-season drought, terminal drought, intermittent drought, and unpredictable drought. Each scenario demands a bean variety with specific physiological and agronomic traits: for example, traits such as early vigour, stomatal regulation, synchronising the fast-growth stage with water availability, and maintaining green leaves and root depth are suggested for intermittent and unpredictable drought. For addressing terminal drought, synchronising the flowering period with water availability, efficient mobilisation of assimilates from source to sink, osmotic adjustment, and root depth are suggested as valuable traits. However, these traits could be more efficient if supported by agronomic management that would enhance nutrient availability, decrease water loss, and increase the soil's water-holding capacity.

RÉSUMÉ

*La sécheresse représente la principale contrainte environnementale qui affecte la production végétale en Afrique subsaharienne. Bien que la sélection de variétés résistantes soit reconnue comme l'une des meilleures solutions, on ne dispose pas d'indicateurs réels permettant de sélectionner des matériaux potentiellement résistants à la sécheresse. Une recherche destinée à identifier les indicateurs de résistance dans le haricot commun (*Phaseolus vulgaris* L.) et le pois chiche (*Cicer arietinum* L.) dans des conditions de stress hydrique de -0,6 MPa a montré que la résistance à la sécheresse (maintien de la turgescence) du pois chiche résultait d'une baisse significative du potentiel osmotique (ajustement osmotique), tandis que dans le cas du haricot, cette résistance était due au maintien d'un potentiel hydrique foliaire élevé et non pas à l'ajustement osmotique. Des expériences en serre ont été réalisées afin de déterminer si le maintien d'un potentiel hydrique élevé dans les haricots en situation de stress était dû à une régulation stomatique et/ou une croissance racinaire. Sept jours de sécheresse modérée réduisait le potentiel hydrique, assorti d'une baisse de la matière sèche aussi bien du haricot que du pois chiche. Une diminution plus importante de la matière sèche du haricot résultait d'une fixation réduite de CO₂, aboutissant à une réduction de 75 % de la photosynthèse pour le haricot, mais de seulement 20% pour le pois chiche. Une baisse importante du taux de photosynthèse réduisait de manière significative les réserves de sucre (glucose, fructose et sucrose) du haricot, expliquant peut-être la raison de la réduction de la biomasse. La diminution importante du taux de photosynthèse était attribuée à une baisse importante de la conductance stomatique. Toutefois, l'efficacité de l'utilisation de l'eau était nettement plus élevée dans le cas du haricot que du pois chiche, indépendamment du régime hydrique. Une expérience en rhizotrons a montré que la densité de longueur des racines du haricot était (deux fois) plus élevée que celle du pois chiche, accompagnée d'un poids racinaire plus élevé. Il en a été conclu que le potentiel hydrique plus élevé du haricot en situation de stress n'était pas dû à un ajustement osmotique, mais dérivait d'une régulation stomatique efficace et d'un système racinaire robuste.*

INTRODUCTION

The common bean (*Phaseolus vulgaris*) is the principal component of farming systems in eastern and southern Africa. It serves as the most important protein source for both humans and animals, and also as a break crop in maize-based systems to avoid declines in soil fertility. However, the productivity of food legumes in the region is limited by frequent drought (Singh et al., 1994). Despite the urgent demand for drought-resistant cultivars, breeders have been slow to achieve this goal due to the challenge of identifying traits that reflect true drought resistance.

MYTHS ABOUT DROUGHT

Definition of drought

Drought denotes a prolonged period without precipitation, which may cause a reduction in soil water content, thereby causing a deficit in plant water. It can be defined either by the external status of water at the boundaries of the plant (soil, air) or by the status of water internal to the plant within the tissue (Tardieu, 1996). The first approach defines water stress as an imbalance between supply and demand, linked to a deficit in atmospheric saturation related to the water potential gradient and leaf area. The second definition associates water stress with the control mechanisms of the plant itself, where plant water status under conditions of low soil-water potential is regulated within the plant by changes in water flux with or without changes in plant water potential (Amede, 1998). However, a decrease in leaf water potential or turgor of a plant *per se* may not truly indicate absolute water stress because some plants with closed stomata and/or inhibited growth could remain without altered plant water status (Turner, 1986; Tardieu, 1996). In East and Central Africa, the following four kinds of drought can occur alone or in combination:

1. **unpredictable drought:** when the total amount of precipitation is comparable to good years but plants are exposed to stress at any stage of growth because of unpredictable and/or uneven rainfall (common in the Great Rift Valley of eastern Africa)
2. **full-season drought:** the amount of rainfall is much lower than normal across the growing season and plants do not get enough water to cover atmospheric demand throughout the growing period (common in most of Sub-Saharan Africa, e.g., north-eastern Ethiopia, Sudan, and northern Africa)
3. **terminal drought:** there is enough water for early establishment and growth but later stages are exposed to deficits in soil water (typical in relay-cropped beans in the Rift Valley—the common practice of relay planting beans in maize fields exposes them to terminal drought)
4. **intermittent drought:** when there is a predictable short dry spell within a growing season and plants are exposed to drought only at one stage of growth (very common in regions with an extended growing period, e.g., Arusha in Tanzania, Areka in Ethiopia)

Yield components and drought

Grain formation in beans is a more intricate process than in cereals in that the development of generative organs in beans is relatively gradual and could be prolonged if external conditions, like water and nutrients, are not optimal. Grain yield in beans is the product of the number of plants (or fruitful axes) per unit area, the number of pods per plant, seeds per pod, and thousand-seed weight. These yield factors determine economic yield and vary over time.

The number of plants per unit area depends on the number of plants that emerge and survive to maturity, for which, drought at the beginning of the growing season is very detrimental. The number of pods per plant or seeds per pod depends on the number of branches produced and the number of well-developed pods and seeds. In this case, intermittent and terminal drought could influence pod formation, seed setting, and seed filling by altering the source-sink relationship by affecting assimilate production, translocation, and partitioning. The number of pods per plant is the most variable factor and is the reason drought at or after flowering can significantly reduce grain yield. Drought at flowering is also known to cause abortion of flowers/pods because of a shortage of assimilates.

Reactions of beans to drought

Whenever bean plants experience a rapid water deficit, bean leaves are known to orient themselves parallel to the incident light; biochemical systems are also alarmed. If the stress is extended to hours or days, then physiological activities will be diverted from functions of cell expansion and growth to mechanisms of restitution of physiological integrity. Bean plants may react to the stressor through short-term strategies, like changes in hydraulic signals or stomatal adjustment. At this stage, the photosynthetic rate could be comparable to that of non-stressed plants but assimilates could be invested to developing long-term mechanisms of stress tolerance at the expense of growth. Bean plants exposed to water stress for days to weeks may develop long-term physiological strategies like altering the leaf area, modifying the root-to-shoot ratio, and the like. When available soil water is reduced, plants usually undergo three progressive stages of dehydration (Sinclair and Ludlow, 1986): at the initial stage of mild drought, assimilation and transpiration are comparable to that of

well-watered plants as long as soil water uptake meets evapo-transpirational requirements. In the second stress period, the photosynthetic capacity of the plant is reduced below the maximum potential level. This is considered to be the most dynamic stage for developing adjustment mechanisms and regulating processes for the maintenance of metabolic activities (Amede, 1998). In the third phase, plants merely survive and delay death. Recovery after rain or irrigation depends on the duration of stress and the species.

MECHANISMS OF DROUGHT RESISTANCE IN BEANS

Drought resistance is polygenic and is commonly accompanied by negative impacts on grain yield. For example, decreasing leaf area or shortening the maturity period of a genotype may improve water availability for the plant by decreasing cumulative transpiration, but it also ultimately decreases economic yield. Selection for drought resistance based on yield alone may not bring about the required genetic shift in specific physiological attributes because the component of genetic variance is low compared with variance in environmental or genotype-environment interactions under stress conditions (Rosielle and Hamblin, 1981). Adaptation to non-drought factors, such as pests, diseases, nutritional status, etc., may also have an overriding effect on the physiological integrity of the plant, thus masking the genetic component of drought resistance of a given genotype. Despite previous disappointments, the drought resistance of legumes could still be improved by manipulating the genetic make-up for efficient water use and effective assimilate partitioning, leading to increases in economical yield.

Many physiological traits have been associated with drought resistance (Turner, 1986; Ludlow and Muchow, 1990). The major mechanisms of drought resistance in beans could be classified as drought avoidance (drought resistance with high plant water potential) and drought tolerance (drought resistance with low water potential) (Turner, 1986; Subbaro et al., 1995). To date, however, no traits are known that confer global drought tolerance (Passioura, 1996). Moreover, short-term responses to water stress at the cellular and sub-cellular level alone may not contribute to yield under conditions of water deficit (Passioura, 1996).

Drought-avoidance mechanisms

Reduced plant size

Grain yield is a converted function of biomass accumulation, which is linearly related to cumulative transpiration (Tanner and Sinclair, 1983). Higher grain yield in legumes is positively correlated with higher plant biomass but negatively with drought resistance (Slim and Saxena, 1993). Amede et al. (1999) showed that in faba beans, drought sensitivity increases with increasing plant height (the correlation was very high: $r = +0.93$). Thus, high-yielding genotypes were drought sensitive, and vice versa. However, it is not yet known whether combining high-yielding and drought resistance traits within a single genotype is possible. Since genotypes that are water saving are commonly low yielding, growing those genotypes in favourable years would lead to a considerable yield loss (Slim and Saxena, 1993).

Drought escape

The most effective strategy of a drought-resistant crop should be to match the most sensitive phenological growth stage to the peak availability of soil water (Richards, 1996), and drought escape could be one of the most reliable strategies of drought resistance for specific environments. However, drought escape in beans is strongly associated with low yield. A yield trial from CIAT on 42 bean genotypes with maturity periods varying from 52 to 83 days showed that differences in maturity were strongly associated with a yield difference of 2000 kg/ha (White and Singh, 1988). In chickpeas, drought escape was a major contributor to yield differences under drought conditions, although few cultivars exhibited real drought tolerance (Slim and Saxena, 1993). Low yields in early-maturing genotypes could be due not only to reduced periods of photo-assimilation but also to shortened remobilisation/translocation times. Despite this, it is not known whether drought-escaping genotypes have alternative tolerance mechanisms.

Developmental plasticity

In comparison to drought-escaping types, genotypes with a potential for developmental plasticity would be much preferable. Developmental plasticity means the ability of a genotype to adjust the duration of different growth phases and the pattern of canopy development to suit moisture availability during the growing season (Subbaro et al., 1995). For instance, peg initiation and elongation in groundnut plants ceases when soil moisture is depleted to 80% of the plant-available water and recommences when soil water is adequate (Chapman et al., 1993). Pod setting and filling at lower nodes during the early growth of some chickpea genotypes ensured that at least some seed setting occurred when there was receding soil moisture (Saxena et al., 1993).

Stomatal regulation

Water loss at the plant level largely depends not only on the size of the transpiring areas (mainly leaves) but also the number and size of the stomata, and the conductivity of the cuticle. In crops, about 90% of total water loss is associated with stomatal transpiration (Monneveux and Belhassen, 1996) followed by loss through the cuticle. The hydraulic conductivity of the cuticle depends upon thickness and nature, as well as the presence or absence, of cuticular wax embedded or deposited on it. Plant transpiration loss could also be modified by the presence or absence of leaf traits, such as the ability to roll up, the colour of the transpirative organ, or reflectance. Moreover, early seedling establishment, early vigour, rapid canopy development in order to minimise evaporation, as well as leaf area maintenance have been suggested as potential mechanisms for drought resistance in grain legumes (Subbaro et al., 1995).

An experiment conducted to evaluate the effect of drought on stomatal closure in beans, compared to chickpeas, showed that in beans, CO₂-fixation decreased by about 75% after three days of mild stress, while in chickpeas, CO₂-fixation was not affected by drought until the sixth day of stress when it showed a 25% reduction (Amede, 1998). In other studies, O'Toole et al., (1977) showed that photosynthesis and transpiration rates in common beans were near zero at plant water potentials of -0.9 to 1.0 MPa, showing that stomatal closure is one of the first steps of defence against drought in beans since it is a more rapid and flexible process than other mechanisms, such as root growth or reduction in leaf area. However, stomatal closure caused a drastic decrease in biomass accumulation (and thereby, grain yield) through reduced photosynthesis (Amede, 1998). Thus, it could be considered as an effective survival strategy for intermittent stress (table 1) but not for terminal stress since yield production is the major goal at this stage of growth.

Table 1. Recommended Traits for Common Beans Grown in Intermittent or Terminal Stress

Intermittent stress	Terminal stress
<ul style="list-style-type: none">• Synchrony of fast growth stages to water supply• Early vigour• Stomatal regulation• Developmental plasticity• Root depth and density• Leaf area maintenance• Other survival strategies	<ul style="list-style-type: none">• Synchrony of flowering/early pod filling to water supply• Mobilisation of assimilates from sink to source• Root depth• Osmotic adjustment of roots and shoots

Efficient roots

Mild drought favours root growth at the expense of shoot growth in order for roots to extend to deeper parts of the soil for available water. Adequate root density throughout the soil profile may increase the diffusion area, thereby improving water availability and uptake. Maintenance of water status under conditions of limited water can be partially attributed to root depth and root length density (Turner, 1986; Subbaro et al., 1995). Slim and Saxena (1993) showed that root depth could be considered as an alternative trait to screen drought-resistant lines. Sponchiado et al. (1989) compared two drought-sensitive bean genotypes (BAT 85 and BAT 477) with two drought-sensitive genotypes (BAT 1224 and A70) under drought-stress conditions at CIAT-Palmira to identify physiological differences of drought resistance. Their results showed that differences in drought resistance among genotypes were associated with root depth, but not root length density, as roots of drought-tolerant genotypes reached a depth of 1.3 m, while roots of drought-sensitive ones only reached 0.8 m. Similarly in chickpeas, genotypes with deeper root systems exhibited higher leaf water potential than shallow-rooted genotypes under drought-stress conditions (Slim and Saxena, 1993). In some cases, crops with higher root length density were not necessarily drought tolerant (Hamblin and Tennant, 1987). Plants often maintain greater root length density than is required by the surface area of the shoot, mainly to minimise the effects of other stress factors such as pests and nutrient deficiency (Passioura, 1983). In addition, it is not known what proportion of the roots is actively involved in water uptake. Extensive root growth at the early stage of plant development could be a disadvantage in semi-arid regions, as it may exhaust the available water prematurely and expose the plant to a critical and terminal drought later on (Passioura, 1996).

Drought-tolerance mechanisms

Mobilisation of assimilate to grain

Screening many lines in the field based on root depth or density is laborious and normally impractical. The simplest method suggested for screening drought-resistant lines in the field is delayed sowing (Singh et al., 1994). Since legumes grown in semi-arid regions commonly encounter terminal drought, sowing a month later than normal in the spring has been effective in differentiating between drought-resistant and -sensitive lines (Singh et al., 1994). As translocation is less affected by drought, compared to photosynthesis and respiration (Boyer, 1976), late sowing may help to evaluate the ability of the genotype to translocate reserves to the sink during the onset of terminal drought. Assimilates could act as a buffer against the effects of water deficits on current assimilation (Ludlow and Muchow, 1990). Assimilates could originate from pre-anthesis or post-anthesis periods, depending on the time of stress and the amount of reserves available in the stem.

Osmotic adjustment

When crops are exposed to drought, they may alter concentrations of cell solutes by allocating resources so that the osmotic potential of the cell is reduced and turgor is maintained (osmotic adjustment). This allows turgor-driven physiological processes, such as stomatal movement and cell growth, to continue despite low plant water potential. It also increases grain yield under stress conditions by modifying the soil-plant water gradient and thereby increasing the amount of water transpired. Osmotic adjustment, through accumulation of effective osmotica, is thus an important mechanism of drought resistance in legumes (Amede, 1998). However, accumulation of solutes in the plant cell *per se* does not guarantee osmotic adjustment. Aside from osmotic adjustment, solute deposition in plant cells under drought stress could have four principal causes (Amede, 1998). First, plants may lose substantial amounts of water that might lead to a reduction in the expansion rate of the tissue (reduced cell volume) and thereby to an accumulation of solutes in the cell. Second, some primary metabolites (proteins, carbohydrates, or lipids) may be degraded at higher stress intensities, and the by-products could accumulate as secondary metabolites in the cell. Third, a decrease in cell elongation (growth) may cause biosynthesis of assimilates to slow, but effective import of assimilates to the sink cells could be high enough to increase the concentration of solutes and ultimately cause a reduction in the osmotic potential of the cell (Kramer and Boyer, 1995). Fourth, under moderate levels of stress, roots may still actively absorb inorganic ions (potassium, calcium, sodium, magnesium, chloride, and others) from the soil. Nutrients may not be utilised by the plant because of drought-induced growth inhibition but, instead, translocated ions may accumulate in the cell, inducing a substantial reduction in osmotic potential (Munns, 1988). Therefore, differentiation between solute accumulation due to a concentration effect and true osmotica is a prerequisite before using solute accumulation as synonymous to osmotic adjustment (Amede and Schubert, 1997).

Comparative research on osmotic adjustment between common bean and chickpea genotypes has shown that solute pool accumulation due to drought in beans was a concentration effect, while the accumulation was a true osmotic adjustment in chickpeas (Amede and Schubert, 1997; Amede, 1998). In other studies, Parsons and Howe (1984) compared common beans with tepary beans (*Phaseolus acutifolius*) for their water relations and concluded that tepary beans were more drought tolerant than common beans because of their higher osmotic adjustment potential, and they suggested transferring the osmotic gene from tepary beans to common beans to improve drought resistance. In general, there is no convincing data to date that suggests osmotic adjustment as a mechanism of drought resistance in common beans.

THE WAY FORWARD IN DROUGHT RESEARCH

There is a clear understanding among researchers that there are no drought-resistance traits of global importance, especially when the expected outcome is beyond survival—it is economic yield. Therefore, it is necessary to characterise the target environment not only from a meteorological aspect but also from that of the plant. It should be characterised in terms of severity of water stress, rate of development of stress, duration of stress, spatial heterogeneity, and the like. Detail characterisation of the environment may help to design and model genotypes with fitting traits.

The other common mistake in drought research is the medium used to identify candidate materials, which is commonly done under inappropriate environments. Testing materials under natural field conditions is a realistic but a challenging one for two reasons: first, there is commonly a year-to-year variation in plant water availability; hence, the experiment should be conducted for many years in many drought-prone environments before reaching a decision. Second, besides water stress, many other factors, like variability in soil water holding capacity, complicate the results; hence, careful attention should be paid to these factors. A

very close type of experimentation is using a rain-out shelter in the field. This could be done even during well-watered years by covering part of the plot with rain-out covers. The most reliable method could be line-source irrigation or pot experimentation. However, the size of the pot should be big enough to allow free growth of roots (a pot with 15 kg soil has been found to be appropriate). The drawback of pot experiments and line-source irrigation is that only a few treatments under a few replications can be handled at a time.

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SESSION 8
GENDER

A COMPARISON OF BEAN PRODUCTION BY MALE- AND FEMALE-HEADED HOUSEHOLDS IN THE BOSSET AREA, CENTRAL ETHIOPIA

Dawit Alemu

ABSTRACT

This study looks at gender differentials in bean production among household types, categorised by the gender of the household head, type of family (monogamous or polygamous), and land ownership. Forty households were randomly selected from each of four household types: male-headed with one wife, male-headed with more than one wife, female-headed, and male-headed landless. Data were collected by interviewing household heads using semi-structured questionnaires in the 1999-2000 cropping season. The results showed that more beans are grown by male-headed households, compared to female-headed households, increasing with the number of wives in the household. The proportion of cropland allocated to beans indicates that it is a major crop in the area, in line with teff, maize, and sorghum. In general, ploughing, planting, piling, and winnowing are activities undertaken by adult male family members, whereas weeding, harvesting, transporting, threshing, and storing are commonly done by all family members, including children. Only seed cleaning is done by adult females, even though few households do this. The decision on which bean variety to plant is heavily influenced by the local market, and all household types sell their beans at local markets immediately after harvest, mainly to generate cash. Only a few said that they sell immediately to avoid storage losses. The male-headed landless household type achieved higher productivity, which has implications for existing land-ownership policies. Existing policies result in fragmentation of farms, which will, again, have a negative impact on productivity because the plot size allocated for beans has a positive effect on yield (as do off-farm activities and ox ownership).

RÉSUMÉ

Cette étude examine la problématique homme-femme au niveau de la production du haricot dans le contexte de différents types de famille, caractérisés par le sexe du chef de famille, la composition de la famille (monogame ou polygame) et la propriété de la terre. Quarante familles d'agriculteurs ont été sélectionnées au hasard parmi quatre catégories : famille avec chef de famille de sexe masculin ayant une seule femme, famille avec à sa tête un homme ayant plusieurs femmes, famille dirigée par une femme et famille sans terre dirigée par un homme. Les données ont été rassemblées en interviewant des chefs de famille sur la base d'un questionnaire semi-directif pendant la saison de récolte 1999-2000. Les résultats montraient que le pourcentage de cultivateurs de haricots blancs est plus élevé pour les familles ayant à leur tête un homme (augmentant en fonction du nombre de femmes composant la famille) que pour celles ayant à leur tête une femme. La proportion de terres de culture consacrées au haricot indique que ce dernier représente une culture essentielle dans la région, de même que le teff, le maïs et le sorgho. De façon générale, le labour, l'ensemencement et le vannage sont des activités entreprises par les hommes de la famille, tandis que le désherbage, la récolte, le transport et l'entreposage sont normalement effectués par tous les membres de la famille, y compris les enfants. Seul le nettoyage des semences est exclusivement le fait des femmes adultes de la famille, mais cette activité n'est pas communément répandue. Le choix de la variété qui sera plantée dépend fortement du marché local et toutes les familles, indépendamment de leur composition, vendent leurs haricots sur les marchés locaux immédiatement après la récolte, principalement pour obtenir des revenus qui permettront soit d'acheter des denrées alimentaires soit de payer des salaires. Seuls quelques cultivateurs évoquent les pertes liées à l'entreposage comme raison de cette vente immédiate.

INTRODUCTION

There is a growing recognition of gender-differentiated interactions among welfare, efficiency, and the success of technology transfers. A number of studies have documented differences in productivity between female- and male-headed households (Udry et al., 1995; Quisumbing, 1996; Addis et al., 1999). Other studies have shown gender differences in the adoption of improved technologies (Mwangi et al., 1999). These findings have shown the need to create a gender-disaggregated framework for targeting policy and interventions.

Most of these studies have focused on households, based on the gender of the household head, and implicitly

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viewed the household as having only one set of preferences (the unitary model of households). This assumption has been a powerful tool for understanding household behaviour, such as the distribution of tasks. Moving further, Alderman et al. (1995) argue that more effective policy instruments can emerge from analysing the processes by which households balance the diverse interests of their members (the collective model).

This study looks at the gender differentials in bean production among household types, categorised by the gender of the household head, type of family (monogamous or polygamous), and land ownership. In addition, it attempts to look at the involvement of household members in the production and decision-making processes on the assumption that understanding the specialised tasks within the household and identifying the division of labour by gender will provide a wider understanding of a given farming system as a whole.

THE STUDY AREA

The study was conducted in Bosset *woreda* (the third level administrative unit under the regional state in Ethiopia), which is the major bean-growing area in the central Rift Valley of Ethiopia. The area is semi-arid with rainfall ranging between 600 mm and 800 mm per year and altitude between 1500 m to 1880 m. The major crops are maize, *teff* (*Eragrostis teff*, the major cereal crop in Ethiopia), haricot bean (*Phaseolus vulgaris*, known as the 'haricot bean' in Ethiopia and hereafter referred to simply as 'bean', and sorghum. In the Eastern Shoa zone, where Bosset is located, 6.45% of the cropland was allocated to beans in the 1998/99 cropping season, compared to a 1.62% of national average (CSA, 1999).

In the study area, 78.3% of households were found to be male-headed with one wife, 2.4% male-headed with more than one wife, 7.68% female-headed, and 11.66% landless. The female-headed households sampled became that way because of either divorce or the death of the male spouse. Landless households are those that do not own their own land; all the landless households in the sample were found to be male-headed and not registered as members of the peasant associations (PAs).

METHODOLOGY

Sampling procedure

Multi-stage semi-random sampling was used to select farmers. First, a production area known as Boffa was selected from the *woreda*, based on the level of production (about 52% of the total area allocated to beans in the 1999 cropping season). The four peasant associations in Boffa (Ararso-Bero, Sara-Areda, Kechachule-Guji, and Dire-Degaga) were then sampled further for household type:

- male-headed with one wife (MHoW)
- male-headed with more than one wife (MHmW)
- female-headed (FH)
- male-headed, landless (ML)

Following this, lists of households were prepared for each PA. The list used for collecting land tax provided male- and female-headed households. For landless households, the list was based on key informants and the Ministry of Agriculture development agents (DAs). Informants and DAs also identified male-headed households with more than one wife. Ten households for each household type were randomly selected from each PA, making a total sample size of 160 households. The data were collected by well-trained enumerators using structured questionnaires under strict supervision of researchers.

Analytical framework

A descriptive approach was employed to compare the socio-economic characteristics and gender differentials among household types. Differences in productivity were assessed using a simple multiple-regression model:

$$Y = \alpha + \beta_{Area} X_{Area} + \beta_{Age} X_{Age} + \beta_{Ox} X_{Ox} + \beta_{Off_farm} X_{Off_farm} + \\ + \beta_{MHmW} X_{MHmW} + \beta_{FH} X_{FH} + \beta_{ML} X_{ML} + \varepsilon$$

Where:

Y	= Yield in <i>quintals</i> (100 kg) per <i>hectare</i>
X_{Area}	= Area allocated for beans (in hectares)
X_{Age}	= Age of the household head
X_{Ox}	= 1, if the household owned ox or oxen, 0 otherwise
X_{OFF_farmx}	= 1, if the household head had off-farm activities, 0 otherwise
X_{MHmW}	= 1, if male-headed with one wife, 0 otherwise
X_{FH}	= 1, if female-headed, 0 otherwise
X_{ML}	= 1, if male-headed landless, 0 otherwise
α, β_i	= parameters to be estimated
ε	= a disturbance term with $\varepsilon \sim \text{IID}$

This relation, of course, is not a production function that can map inputs to outputs, determined by biology and the technical efficiency with which inputs are used. Instead, it is a reduced form, which provides a test of the efficiency of the allocation of inputs.

The following assumptions were hypothesised:

1. The size of the area allocated will affect the yield either positively or negatively.
2. Ox ownership will have a positive effect on yield.
3. Age of household head will have a positive effect on yield because experience in production is positively correlated with age.
4. There will be yield difference among household types because they have different resources available and different use-patterns and production constraints.

SOCIO-ECONOMIC CHARACTERISTICS

Household head

Household heads are characterised in terms of age, religion, level of education, and off-farm income (table 1). The average age of the female and male heads of households was similar, about 50 years, whereas the heads of landless household were 29 years old on average. Ninety-five percent of the households were Christian and the remaining, Moslem. All of the heads of households with more than on wife were illiterate, and about 98% of the female heads of households were illiterate, whereas about 75% of the landless heads of households (the younger generation) were illiterate.

The involvement of household heads in generating off-farm income varied among household types: 35% of MHoW, 8% of MHmW, and 20% of female-headed and landless households had off-farm income. The types of activities for generating off-farm income also varied. The main source for MHoW households was selling firewood and for female-headed households it was selling alcohol (table 1).

Household characteristics

Household size

MHmW households had the largest families (the most labour available), followed by MHoW households (table 2). Female-headed households had the smallest families. Except between female-headed and landless households, the differences are statistically significant.

Resource ownership

Table 3 summarises the differences among household types in resource ownership, i.e., type of house owned, number of oxen, and land size. In areas where there is erratic rainfall, the scheduling of farm activities is very important. One of the limiting factors is the availability of oxen, and we found a difference among

Table 2. Characteristics of Household Head

	Household type				
	MHoW	MHmW	FM	ML	Total
Age of household head					
Average in years (Standard Deviation)	49.35 (11.90)	50.90 (10.37)	51.20 (13.54)	28.57 (4.86)	45.01 (14.25)
Religion (%)					
Moslem	5	5	2.50	7.50	5.00
Christian	95	95	97.50	92.50	95.00
Education (%)					
Illiterate	90	100	97.50	75.00	90.06
Off-farm income (%)					
Farmers with off-farm income	35	8	20	20	22
Types of off-farm activities (%)					
Labour	10	—	—	—	3
Trade	5	—	5	10	5
Selling firewood	18	5	2	8	8
Land leasing	2	3	—	—	1
Local alcohol seller	—	—	18	2	5

household types in the number of oxen owned. At 32%, female-headed households had the lowest percentage of ox ownership.

Type of house can be seen as an indicator of wealth: owners of iron-roofed houses are richer than those with a grass-roofed house. Male-headed households with one wife and landless households tended to have grass-roofed houses, whereas about 13% of MHmW and female-headed households lived in iron-roofed houses. For MHmW households, house type refers to the house where the first wife lives. It is a tradition that the first wife is more respected than the other wives. In many cases, there are grass-roofed houses for the other wives near the iron-roofed house.

Table 3. Family Size

	Household Type				
	MHoW	MHmW	FH	ML	Total
Household size	6.25 (2.05)	9.45 (3.19)	3.98 (1.73)	4.18 (1.34)	5.96 (3.10)
Male adult	1.93 (1.00)	1.83 (1.03)	1.00 (0.88)	1.10 (0.30)	1.46 (0.94)
Female adult	1.45 (1.01)	2.63 (1.23)	1.15 (0.48)	1.03 (0.16)	1.56 (1.04)
Children	2.88 (1.45)	5.00 (2.45)	1.83 (1.60)	2.05 (1.15)	2.94 (2.13)

Note: Entries are mean values with standard deviation in parenthesis.

In this study, the female-headed household were those where the household head was either widowed or divorced. In either case, they inherited some wealth from their husbands, which could explain why most of the FH households had iron-roofed houses. Moreover, these households commonly get support from their sons and daughters.

In all household types, there was no division of land among household members. Even in polygamous households land was cultivated jointly.

The average farm size (cultivated and uncultivated land) for each household type is shown in table 3. The difference in farm size between male-headed households (both types) and female-headed households is statistically significant.

GENDER DIFFERENTIALS IN BEAN PRODUCTION

The gender differentials were analysed in terms of the importance of bean growing, cropland allocation, variety preference, family members' involvement in agronomic practices, and differences in productivity among household types.

Importance of growing beans

The percentage of bean growers is higher for male-headed households, compared to the female-headed households, ranging from 58% of female-headed to 85% of MHmW households (table 4).

Table 4. Households Growing Beans and Their Reasons

	Household type			
	MHoW	MHmW	FH	ML
Bean growers (%)	75	85	58	78
Reasons for growing beans				
Beans can be sold for a better price	96	94	100	97
Beans are important for home consumption	90	56	9	73
Beans do not require much labour	7	18	4	17

Table 5. Resource Ownership (Percent of Households)

Number of oxen owned	Household type				Total
	MHoW	MHmW	FH	ML	
0	50	27	68	52	49
1	22	38	15	30	26
2	20	25	12	18	19
> 2	8	10	5	0	6
Type of house owned					
Grass-roofed	100	88	88	100	94
Iron-roofed	0	12	12	0	6
Land ownership					
Average (Standard Deviation)	2 ha (4.27)	2.5 ha (5.37)	1.3 ha (3.03)	1.6 ha (3.94)*	1.9 ha (4.56)

Note: Land is traditionally measured in *kert*, which is approximately equal to 0.25 ha. Amounts shown here are in hectares (converted from *kert*).

*Amount of land under cultivation.

The survey looked at reasons for growing beans; more than 90% of all household types responded that beans could be sold for better price (table 4). This shows that in the study area beans are considered a cash crop. All female-headed households responded that they grew beans because of the better price, compared to other crops.

Land allocation for beans

The proportion of total cropland allocated to beans ranged from 30% to 40% (table 5), indicating that beans are a major crop in the area in line with *teff*, maize, and sorghum. Even though fewer FH households grew beans, compared to the other household types, they allocated a higher proportion of the land they own to beans, mainly because they believe that beans can be sold for a better price than other crops. The MHmW households allocated larger amounts of cropland for beans, compared to the other household types. The differences in mean land size allocated for beans among household types are statistically significant.

Preference for bean varieties

In the study area the decision on which type of bean variety to plant was heavily influenced by the local market. Almost all the interviewed farmers (96%) responded that they preferred to plant the variety called 'Mexican 142' (locally called 'Lemat') due to its higher price at the local market, attributed to its white

Table 6. Percent Cropland Allocated to Beans, Boffa Area, 1998/99 Crop Season

	Household type				Total	
	MHoW	MHmW	FH	ML		
Growers (%)	75	85	58	78	73.75	
Area allocated to beans	≤ 0.25 hectare	17	24	26	23	
	> 0.25 hectare to ≤ 0.5 hectare	47	26	39	29	
	> 0.5 hectare to ≤ 1 hectare	37	32	35	29	
	> 1 hectare	—	18	—	16	
	Average size in hectares	0.6	0.7	0.5	0.7	0.6
	Standard Deviation (SD)	(0.85)	(1.90)	(0.92)	(1.90)	(1.55)
Average share of cropland in beans	0.33	0.30	0.40	0.39	0.33	
Standard Deviation (SD)	(0.19)	(0.14)	(0.19)	(0.16)	(0.14)	

colour. Only 4% of the bean-growing farmers grew local varieties. Local varieties were grown by none of the MHoW households, 60% of the MHmW, 20% of the FH, and 20% of the ML.

In answer to the question, “What is the usual source of seed?” two major sources were indicated: from own stock and from the local market. Forty percent of MHoW, 71% of MHmW, 30% of FH, and 58% of ML households retained their own seed from their own production. The rest bought from the local market at planting time—at a higher price and commonly low quality.

With respect to consumption preferences, the majority of the farmers consumed beans bought from warehouses. These were of low quality and mixed, locally called *megazene* (warehouse). This is because they can buy more in terms of quantity for home consumption by selling a small amount of their own quality beans. The price of *megazene* ranged from 50 to 62 ETB/quintal (US\$6.80 to US\$8.44 per 100 gm, at the exchange of 7.35 ETB = US\$1.00 at the time of this survey).

Household differences in gender division of labour

To compare family members’ involvement in different agronomic practices, family members were grouped into adult male, adult female, and children. Anyone aged 15 years or older was considered an adult.

In general, ploughing, planting, piling, and winnowing are activities undertaken by adult male family members, whereas weeding, harvesting, transporting, threshing, and storing are commonly done by all family members, including children. Only seed cleaning is done by adult females, even though only a few households undertake this activity. A chi-square test was performed to see whether there was a difference among household types in the involvement of family members in each agronomic practice. The results show that there is a significant difference.

Seed cleaning

Seed cleaning is not a major activity. It was done by 45% of ML, 23% of MHoW, 13% of FH, and 12% of MHmW households.

Ploughing

In the majority of households (over 52%), adult males did the ploughing. In FH households, it was done by non-family labour (hired labour or a relative). Twenty-two percent of FH households undertook bean production for a share (production share arrangements are a common practice where a household with excess land or shortage of labour, as in the case of FH households, gives land to a farmer in return for a share of the produce, commonly 50% of production); about 13% of them got labour from relatives without payment. In 38% of male-headed households (both types), children were also involved in ploughing.

The majority (61%) of landless households did not undertake a second ploughing and 35% of FH households did not undertake a second ploughing.

Sowing

Sowing was done by adult males. In about 35% of FH households, sowing was done by non-family labour.

Fertilising

The majority of households did not fertilise their bean fields: 76% of male-headed, 91% of female-headed, and about 58% of ML households. In those households where beans were fertilised, the activity was conducted mainly by adult males with some involvement of adult females.

Weeding

Except for FH households, bean fields were usually weeded. In male-headed households, all family members participated, whereas in the majority of ML households, only adults did the weeding.

Harvesting

Except for FH households, where adult female and male family members and non-family labour did the harvesting, all family members participated in bean harvesting: 47% of MHoW and 65% of MHmW households. In about 84% of the landless households, harvesting was done by adults of both sexes. In about 35% of the FH households, harvesting was done by non-family labour, paid for by a share arrangement for labour and oxen in about 35% of FH households. The rest is from the labour of unpaid relatives.

Transporting

All family members in all types of households participated in transporting harvested beans for threshing, except in landless households, where adult females and males took the responsibility. In female-headed households, non-family labour did in this—as in other activities.

Piling

Piling was an activity done predominantly by adult male members in all household types. In about 22% of FH households, hired labour was involved in piling.

Threshing

There was a significant variation among households, even within each household type, in the participation of household members in threshing. In male-headed households, all household members were involved whereas in FH and ML households, adult members of both sexes took the responsibility.

Winnowing

Adult males in all household types did the winnowing. In male-headed households, children also participated.

Storing

Adult family members did storing, with more participation from male adults. The activity was not undertaken in about 3% of MHoW and about 6% of MHmW households.

Differences in productivity

The average yield in the area was 450 kg/ha, with a huge variation in yield even within each household type: 340 kg/ha for FH, 350 kg/ha for MHoW, 420 kg/ha for MHmW, and 450 kg/ha for ML households (CSA, 1999). The values of the coefficient of variation range from about 125% for FH households to 52% for MHmW. The yield level achieved in the area is far below the level achieved in the zone—or even at the national level—may be due to the rainfall pattern in the area during the cropping season.

Table 6 summarises the variables used to estimate the differences productivity, which are described in terms of their mean value and standard deviation.

The regression estimates revealed that plot size allocated for beans, ox ownership, off-farm activity, and the dummy variable for landless households are statistically significant and have a positive effect on the yield achieved per unit area. Households with larger allocations for beans achieved a higher yield per unit of area. Farmers with an ox or oxen had higher yields per unit area, compared to those without oxen, which is in line with farmers' own assessment of their major production constraint: lack of oxen. Farmers involved in off-farm activities had higher yields than those with no off-farm activity, which could be explained by the greater ability of those who have an off-farm income to purchase inputs.

There was no statistically significant difference in productivity among MHoW, MHmW, and FH households. Landless households had higher productivity than the others, which has implications for existing policies on land ownership. Under the current policy, land cannot be sold or exchanged, which limits the transfer of land to efficient producers. In addition, it causes a further reduction of farm size, as the only way of acquiring land remains inheritance. The fragmentation of farms will have a negative impact on productivity because plot size has a positive correlation with productivity.

Table 7. Yield-Determinant Variables in Bean Production

Description	Mean	Standard deviation
<i>Dependent variable</i>		
Yield (100 kg/ha)	382.83	3.2187
<i>Explanatory variables</i>		
Area allocated to beans (in hectares)**	0.64	0.3871
Age of household head	44.7	14.3828
Ox ownership dummy = 1 if own an ox, 0 otherwise**	0.58	0.4948
Off-farm income dummy = 1 if off-farm income, 0 otherwise**	0.19	0.3911
Household type dummy (MHoW is reference)		
MHmW = 1 if male-headed household with more than one wife, 0 otherwise	0.29	0.4548
FH = 1 if female-headed household, 0 otherwise	0.19	0.3948
ML = 1 if landless household, 0 otherwise**	0.26	0.4419

** Significant at $\alpha \leq .05$.

*** Significant at $\alpha \leq .01$.

GENDER DIFFERENTIALS IN BEAN MARKETING

Markets

Farmers were aware of the cost of transportation to nearby town markets, which equalised the price difference between the town and local markets, so all household types sold their beans in the local market. Household heads undertook the marketing in the majority of the households, except ML households, where selling was done by both female and male adult members of the family. Few households did not sell beans. A chi-square test showed that there was a significant difference in the involvement of family members among household types in selling beans (table 7).

Table 7. Involvement of Family and Nonfamily Members of Bean-Growing Households in Selling Beans

Family and nonfamily members	Household type				χ^2
	MHoW	MHmW	FH	ML	
Adult males	21 70%	21 62%	1 4%	9 29%	122.10**
Adult females	1 3%	1 3%	21 91%	—	
Children	—	—	—	—	
Adult females and males	6 20%	7 21%	—	20 64%	
Adult females and children	—	—	—	—	
Adult males and children	—	2 6%	—	—	
All family members	1 3%	1 3%	—	—	
Do not undertake the activity	1 3%	2 6%	1 4%	2 6%	
Nonfamily members	—	—	—	—	

** Significant at $\alpha \leq .05$.

Almost all the sampled farmers said that they sold beans immediately after harvest to generate cash either for food items or loan settlement. Only a few responded that they sold immediately to avoid storage loss.

Variations in bean price

Since almost all farmers sold beans immediately after harvest, it was not possible to assess price variations over time. But in looking at data over three months, we observed that there was a price difference among household types, with FH households selling at a higher price than other household types. Because all household types grew only one variety (Mexican 142), it is possible to compare price variations among households (table 8).

Table 8. Selling Time and Price Variations among Household Types

	Household type							
	MHoW		MHmW		FH		ML	
Time of sale	\bar{X}	SD	\bar{X}	SD	\bar{X}	SD	\bar{X}	SD
October	22.60	18.97	22.64	22.12	—	—	19.73	19.15
November	23.92	14.43	23.84	15.29	23.85	8.74	22.85	8.85
December	—	—	—	—	27.21	0.00	21.77	0.00
Total average	23.26	16.99	23.54	17.23	24.49	12.65	22.21	13.62

Note: \bar{X} – average price in US\$/100 kg; SD – standard deviation.
The difference between the price obtained by FH households and other household types is significant ($\alpha \leq .1$).

Statistical tests for the mean price difference between household types show a significant price difference between households except between MHoW and MHmW and between MHmW and FH households.

The reason for FH households getting a better price is that in addition to the time of sale, females tend to sell retail, whereas males sell in bulk. In addition, females have better bargaining abilities and are capable of predicting price variations, even within a single market day.

DECISION MAKING IN BEAN PRODUCTION

Farmers were asked the role of the household head, wife (or wives), and relatives in making decisions, ranging from which variety to plant to the use of the income from bean sales.

All decisions were made either by the household head (HHD) alone or by the HHD in consultation with his wife or wives (table 9). In the majority (over 51%) of MHoW households, decisions were made by the HHD in consultation with his wife, whereas in MHmW households, decisions were made predominantly by the HHD. In FH households, decisions were made by the HHD, except for a few cases where either adult family members or relatives were consulted. In households where production was undertaken under a share arrangement (common for FH households), decisions were de facto made through negotiation, even though the household head de jure claimed that decisions were made by her/him. In ML households, decisions were predominantly made by the HHD in consultation with his wife.

The implication of these findings is that in addressing the issue of transferring improved technologies efficiently, one can see which family members in each household type should be first consulted and convinced. In the case of MHoW and ML households, both the HHD and the wife should be involved in any extension activity concerning beans, whereas in FH and MHmW households, the HHD is the one who should be consulted.

PRODUCTION CONSTRAINTS

Farmers were given a list of production constraints and were asked to identify and prioritise them, taking their own situation into consideration. The result is summarised in Table 10. Ranks were determined based on the highest percentage of households giving the same rank for a constraint. Blank entries imply that the constraint under question was not identified as a production constraint.

Table 9. Decision Making among Household Types in Bean Production (Percent of Households)

Decisions	Household type							
	MHoW		MHmW		FH		ML	
	HHD	Both	HHD	Both	HHD	Other	HHD	Other
Which variety to plant	46	54	78	22	93	8	45	55
Accepting a new variety	46	54	81	19	93	8	45	55
How much to plant	49	51	84	16	93	8	50	50
Which plot to use for each crop	49	51	84	16	93	8	47	53
Whether to use fertiliser	41	59	70	30	93	8	45	55
When to sell	28	72	57	43	93	8	29	71
How much to sell	28	72	57	43	93	8	29	71
For what purpose to use income from sale	28	72	59	41	93	8	34	66

Note: HHD = decision is made by household head alone; Both = both HHD and wife or wives make decisions; Other = HHD and either adult family members or relatives make decisions.

Table 10. Production Constraints and Their Priority among Household Types

Constraints	Household type			
	MHoW	MHoW	FH	ML
Lack of improved seed	2	2	2	2
Shortage of land	—	—	4	3
Shortage of oxen	1	1	1	1
Lack of fertiliser	4	3	5	4
Shortage of rainfall	3	4	3	5

The main production constraint for all household types was lack of oxen, followed by lack of improved bean seed. Labour shortages, problems with disease and pests, and price variability were not identified as constraints. A shortage of land was identified by FH and ML households as a constraint.

The erratic nature of the rainfall pattern in the area makes scheduling of agronomic practices more important. When the rain falls, there is a competitive demand for oxen for land preparation and planting of almost all crops in the area. Therefore, those farmers without oxen cannot time farm activities effectively, which may result in the total loss of the crop.

Due to the nature of subsistence farming and the fear of losses in storage, the majority of the farmers are obliged to buy seeds during planting, which means paying a higher price or accepting lower quality. The Ministry of Agriculture (MOA) has tried to address this problem by providing improved bean seed for selected farmers just for the purpose of seed multiplication. The intention was to buy the seed back from these farmers and sell to other farmers at a fair price. The arrangement was to keep the seed until planting and sell back to the MOA at the price set immediately after harvest, which, because of the price arrangement and the cost incurred in storage, is obviously a disincentive for these farmers.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

This study looked at the gender differentials in bean production among household types, categorised by the gender of the household head, type of family (monogamous or polygamous), and land ownership. In addition, it attempted to look at the involvement of household members in production and decision-making processes.

The analysis shows a high percentage of bean growers, 57.5% of female-headed to 85% of MHmW households. The proportion of total cropland allocated to beans ranges from 30% to 40%, indicating that beans are a major crop.

In the study area, the decision on which type of bean variety to plant is heavily influenced by the local market demand. Almost all the interviewed farmers said that they preferred to plant 'Mexican 142' because of its higher price at the local market.

There is a significant difference among household types in the involvement of family members in each agronomic activity, which is related to the availability of labour within each household type. In general, ploughing, planting, piling, and winnowing are activities undertaken by adult males. Weeding, harvesting, transporting, threshing, and storing are commonly done by all family members, including children. Only seed cleaning is done by adult females, even though only a few households undertake the activity.

Beans are considered a cash crop in the study area, with more than 90% of the households in all household types saying that they grow beans because they can be sold for better price. All household types sell their beans at the local market rather than nearby town markets because of transportation costs. Almost all the sampled farmers said that they sell beans immediately after harvest mainly to generate cash for food items or loan settlement. Only a few responded that they sell immediately to avoid storage losses. Female-headed households sell at a significantly higher price than other household types because females sell retail (whereas males sell in bulk) and females have better bargaining abilities and are more sensitive to price variations.

All decisions (from which variety to plant to the use of income from bean sales) are made either by the household head alone or in consultation with his wife or wives. In the majority of MHoW households decisions are made by the household head in consultation with his wife, whereas in MHmW households, decisions are tend to be made by the household head alone. In FH households, decisions are made by the household head; in a few cases adult family members or relatives are consulted. In addressing the issue of transferring improved technologies efficiently, one can see from these results which family members in each household type should be first consulted and convinced. In MHoW and ML households, both the household head and the wife should be involved in any extension activity concerning beans, whereas in FH and MHmW households, the household head is the one who should be consulted.

The main production constraint in the area is identified as a lack of oxen, followed by lack of improved bean seed. Female-headed and ML households have problems with land shortages.

The simple multiple regression analysis showed that there is a difference in productivity only between landless and other household types, with higher productivity achieved by landless households. The plot size allocated for beans, off-farm activity, and ox ownership have a positive effect on yield.

The higher productivity achieved by ML households has implications for existing policy on land ownership, prohibits land from being sold or exchanged. This limits the transfer of land to efficient producers and causes further reduction of farm size because the only way of acquiring land is through inheritance.

Recommendations

Most studies on gender differentials are meant to generate information that can assist the formulation of more effective policies to address existing production problems.

In this study, female-headed households were found to have the most limited resource ownership (land and oxen), compared to the male-headed households.

There was no statistically significant difference in productivity between FH, MHoW, and MHmW households, but ML households had higher productivity than the other household types.

Any extension activity regarding agronomic practices in bean production should consider household types, as there is a difference in the involvement of household members in different types of households.

The significant positive effect of plot size on productivity and the higher productivity achieved by landless households implies a need for further study (looking at all crops and livestock) on current land ownership policy and its effect on productivity.

Lack of oxen, which is the major production constraint that had a significant effect on productivity, has to be addressed through better animal-production practices, especially by minimising the death of animals during drought. Formal and informal credit systems should also be encouraged to alleviate the problem.

Even though many improved bean varieties appropriate to the area have been released, farmers predominantly plant “Mexican 142” and stated that varieties other than the local ones were not available. Rigorous efforts should be made to provide farmers with a choice of improved varieties. The Ministry of Agriculture’s effort to provide farmers with improved varieties should be strengthened and the pros and cons of the current seed dissemination strategy should be analysed. A strategy that can provide sustainable economic incentives for seed multipliers should also be designed.

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THE ROLE OF WOMEN IN BEAN PRODUCTION FOR FOOD SECURITY IN SUDAN

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ABSTRACT

In Sudan, it is generally acknowledged that women play a very important role in the production and preparation of food and marketing. The objective of this study was to evaluate the role played by rural women in bean production and to examine the access of rural women to improved agricultural technology. The study revealed that the contribution of rural women to bean production is significant. They work as farm owners, partners, and farm labourers and are involved in planting, weeding, and harvesting. The participation of women in these activities is an indication that the users of a technology need to be considered. The study also showed that the adoption of production technology by women farmers is satisfactory and comparable to that of male farmers. Despite this fact, there is a need for more extension targeted to women by female extensionists to help increase production and, thus, food security in Africa.

RÉSUMÉ

Au Soudan, il est généralement reconnu que les femmes jouent un rôle très important dans la production des cultures vivrières. Elles mènent à bien le processus de production, la préparation de la nourriture et la commercialisation. La présente étude avait pour objectif d'évaluer le rôle joué par les femmes rurales dans la production du haricot et d'examiner l'accès de ces femmes aux technologies agricoles améliorées. Elle a révélé la contribution importante des femmes rurales à la production du haricot, celles-ci travaillant en tant que propriétaires d'exploitation, partenaires ou employées agricoles et prenant part au semis, au désherbage et à la récolte. La participation des femmes à ces diverses opérations implique la nécessité de les prendre en considération en tant qu'utilisatrices des technologies. L'étude montrait également que l'adoption de la technologie de production par les femmes agricultrices est satisfaisante et comparable à celle des agriculteurs. Il est toutefois nécessaire d'intensifier la vulgarisation axée vers les femmes par des agents de vulgarisation féminins afin d'aider à augmenter la production et, de cette manière, la sécurité alimentaire en Afrique.

Key words: *Bean, adoption, extension, food security*

INTRODUCTION

Agriculture is the backbone of the Sudanese economy, contributing significantly to the gross domestic product—30% to 40% over the last decade (Bank of Sudan, 1999). It is also the main source of foreign exchange earnings. Agriculture employs about 70% of the population and provides livelihoods for almost all rural people. In addition, it provides raw material for all processing industries.

The contribution of women to agricultural production in the Sudan is substantial—a claim supported by statistical evidence. However, this contribution has varied from one area to another depending on variations in socio-cultural and economic factors (Ahmed, 1992). Modernisation is often a factor that reduces women's contributions to agriculture (Basher, 1987).

OBJECTIVES AND METHODOLOGY

The objectives of this study were to explore the role played by rural women in bean production and examine the access of rural women to improved agricultural technology. The study aimed to identify the main agricultural activities in which women participate and to quantify the time spent in the field. The methodology was an exploratory survey to collect primary and secondary information on the role of women in the production of common beans (*Phaseolus vulgaris*) in the Sudan. The field survey was conducted on a

random sample of 40 female farmers in the 2001 production season in the public and private pump schemes in the Nile River State (for dry beans) and in Khartoum State (for exported green beans).

THE ROLE OF WOMEN IN AGRICULTURE

As females constitute more than 49 percent of the Sudanese population, they can play a great role as a labour force in various part of the country (UNFPA/CBS, 1999). Sudan's 1993 census showed that an average of 25% of the female population were economically active, compared to 71% of males. However, the census underestimates women's economic productivity, and there is a wide range of regional differences. A high percentage of active females was reported in the states of Darfur (58.5%) and Kurdofan (45.9%) in western Sudan due to the participation of women in traditional agricultural activities (1993 Census). In addition to household activities, they have to fetch water and fuel-wood, which are very time consuming. Thirteen percent of females in Khartoum State are economically active, 13.7% in the eastern states, 10.5% in the central states, and 6% in the northern states.

The role of women in agriculture in Sudan is generally acknowledged. In addition to the significant role they play in agricultural production, women also prepare food and do the marketing. They are actively involved in the production of vegetables for both local consumption and export, providing support and livelihood for their families. Women's activities extend throughout food production and processing. However, the role of women is hardly mentioned and they lack access to the means of production.

PRODUCTION OF THE COMMON BEAN IN SUDAN

The common bean is one of the most important food legumes in the Sudan, consumed in almost all parts of the country as a major source of low-cost protein for the middle- and low-income segments of the population. Production is mainly concentrated in the Nile River State, particularly in the Barbar-Damar and Shendi-Salawa areas, taking advantage of the relatively cool winter compared to the rest of the country. The area planted to the common bean was about 14,400 ha in the 2000 season. To meet rising consumption demands, the dry bean was imported from Ethiopia, resulting in a decrease in the cultivated area to 5250 ha in the 2001 season in the Nile River State.

In Khartoum State, green beans have been cultivated on small private farms along the Nile River and in intensive production in large farms for export. Sudan imported about 27 tons of green beans in 1997 (valued at US\$ 31,000) but it also exported about 903 tons of green beans to European countries in 1998.

The dry bean varieties include Sarrag, RO2/1, Basabeer, Giza, and traditional varieties, whereas the green bean varieties include bobby beans, fine beans, extra-fine beans, Giza-3, haricot, and needle beans. The average productivity of dry beans in the Nile River State is about 2.0 tons/ha, which is lower than that of other bean-producing countries. The major factors responsible for low productivity are (1) low yields of traditional varieties, which are susceptible to pests and diseases, (2) poor management practices, (3) inadequate control of weeds and pests, and (4) inadequate credit and marketing facilities and traditional crop-sharing arrangements, which often prevent adoption of improved production technologies because of a conflict of interest with tenants, land owners, and owners of water pumps. The average productivity of green beans in the Khartoum State ranges between 5 tons/ha and 10 tons/ha.

Research on common beans has been going on in Hudeiba Research Station, with a focus on improving the productivity and quality of the crop through plant breeding and crop husbandry. Improved varieties (with a significant increase in yield) have been developed but their dissemination to farmers is still slow. It is evident that yields could be considerably increased if improved technologies are adopted. Self-sufficiency is within reach provided that inputs are secured in a timely way and more farmers adopt the improved technologies. Thus, it is necessary to strengthen extension and expose more farmers to the package of improved practices.

The farming systems where the common bean is produced are characterised by a system of crop sharing that involves the pump owner (known as the 'scheme owner') and sharecroppers (who may or may not own the land). The production relationships between the two parties are based on resource participation. The pump owner is responsible for providing water, while the sharecropper provides labour for field operations. Other inputs are shared according to specific percentages, depending on the input, and the produce is equally shared. These traditional production relationships create conflicting perceptions about the use of new technologies if they alter the pre-existing shares. The irrigation regime illustrates this well: farmers, who have limited control of the level of water they receive, might like to adopt a higher irrigation level, but the

pump owner, who has full control of the water (and who is solely responsible for the cost of irrigation water), would prefer the lower technology level.

THE ROLE OF WOMEN IN BEAN PRODUCTION

Women are economically important members of their households and they usually have multiple economic roles, dividing their time between home and farm activities. These unpaid activities are very time consuming and make a vital contribution to the economy of poor rural households. Although women carry out heavy duties and responsibilities, ensuring the food security and nutritional well-being of their households as well as that of the extended family, they do not get the recognition and opportunity to improve their status, develop their skills, or change their position. Apart from land preparation (which is carried mechanically) and irrigation (which is dominated by men because of the physical nature of the work), all other agricultural activities are performed by women. In the Nile River and Gezira States, women are involved in the planting, weeding, and harvesting of dry beans.

Women are not paid for weeding; they do it to feed their animals and sell their milk. In harvesting, women represent 50% of the labour force. They are not paid in cash; they only take part of the hay for their animals, in addition to some produce. In Gezira State, they did these activities because the common bean is a family crop. In Khartoum State, women also participate in grading and packing produce (green beans) for export. Women make up the entire labour force in green-bean production because they accept lower wages than men. Also, women can exert more effort and such a crop demands intensive activity. Men receive higher wages for less-demanding activities, such as fodder production. At the time of our survey, the daily wage of women in Khartoum State ranged between SD 200 to SD 300 (approximately US\$0.80 to US\$1.20). The majority of the working women were above 35 years of age. Sixty-two percent of the working women in Khartoum State were married, 17% divorced, 14% single, and 7% widowed. Many of them are displaced persons. With respect to their education, the survey indicated that about 77% of them were illiterate while 23% of them had an elementary education (Ishtiag, 2000).

The survey showed that the adoption of production technologies by women farmers is satisfactory and comparable to that of male farmers. Their work during harvesting green beans is appreciated and outweighs that of men. They work as farm partners in the Gezira and Khartoum states and as farm labourers in the Nile River and Khartoum states. In green-bean production, women are expected to spend about 38 working days in the field, planting, replanting, thinning, weeding, harvesting, grading, and packing.

IMPORT AND CREDIT POLICY

Producers complain about imports and claim that large quantities traded through the Ethiopian border have disrupted the crop supply and prices. Imports have increased the market supply, leading to a drop in prices and directly affecting the cropped area and, finally, the women workers. Policymakers should consider regulation of imports and border trade with respect to the level and timing of imports in relation to the domestic supply so that a stable supply and prices can be attained. It could be observed that following the adoption of the new open-market policies and their implications for credit and pricing policies and, in the absence of appropriate policies to alleviate their negative effects, the policy environment does not encourage the use of higher technology.

The farming systems under which the common bean is produced are characterised by small private pump schemes, which, for long time, enjoyed subsidised credit and inputs. Following the enforcement of the open-market policies in the early 1990s, new finance policies were adopted by the Agricultural Bank of Sudan and commercial banks. These new policies require credit to be extended only to farmers with bank accounts, and the level of credit is proportional to the size of the customer's deposits. Most producers have no savings to deposit and are therefore ineligible for credit. This has negatively affected farmers' access to and use of technologies, resulting in lower adoption levels. Farmers attributed the decreasing trend in adoption levels of technology, particularly the irrigation regime, to the high cost of production, unavailability of inputs, and lack of credit, which are all related to the set of policies discussed above. Farmers may also cultivate the common bean with no tillage because of the lack of tractors (in some cases) and with the objective of decreasing production costs (in most cases).

The issue of women farmers and their access to technology is complex. Despite the fact that women are involved in the planting process, they do not receive extension services. This is partly because of cultural

restrictions that prevent extension officers from meeting women farmers and domestic responsibilities that limit women's mobility, making it harder for them to attend meetings and courses away from home.

With respect to credit, many women are unable to meet the collateral required by the bank to get credit. Very few women own land or have deeds of ownership to physical property such as homes. Such deeds are always in the names of men. So, their limited access to resources—be it land, credit, extension services, or appropriate technology—is the major constraint that women face with respect to food security in Sudan.

LIMITATIONS

Despite the significant contribution of women in production, there are many limitations that cripple them in their activities. The following factors greatly contribute to the neglect of female farmers:

1. Women's indispensable role as mother—caring for babies and children and managing the entire family—exerts a time constraint, keeping them from participating effectively in agricultural production.
2. Women suffer from cultural and social structural biases as a result of practices related to the ownership and inheritance of land.
3. Limited access to resources—credit, land, and other operating inputs, such as research and extension services—because of legal, social, and institutional factors create barriers to women and circumscribe male-female interactions. This is in addition to the fact that women have less mobility.
4. Women are affected by technological biases; i.e., technology delivery targets male farmers because most extension staff are males.
5. Women lack input into decision making because the tradition is that men are the authority figures responsible for making key farm decisions.
6. Formal and informal education of women is limiting; however, this situation is expected to change in the next generation.

SUMMARY AND CONCLUSIONS

The call for the advancement of women in agriculture is becoming increasingly loud and clear. Rural women are an enormous resource and are crucial to agricultural production. This study explored the role of women in production practices for the common bean in the Sudan, revealing that rural women make a significant contribution to agriculture, in general, and bean production, in specific. Women are involved in the planting, weeding, and harvesting of dry beans in the Nile River and Gezira states. In addition, in Khartoum State, they effectively participate in grading and packing green beans for export. The participation of women in these operations necessitates consideration of the user's perspective of technology.

Results also showed that only a few farmers are exposed to technologies (improved seeds). Farmers in general have weak contacts with the extension and other agricultural service departments, while women lack even this contact: more extension efforts are needed. The effectiveness of demonstration programmes and their success in exposing a broad range of farmers to the recommendations is an important issue to address. Following the recently adopted free-market policies, the policy environment is not conducive to the use of high technology. Correcting this situation would need policy-reform measures in the following areas:

1. monitoring imports and regulating illegal border trade with respect to levels and timing of import flows in relation to the domestic supply so that a stable supply and prices could be attained
2. credit policy reform to ensure credit eligibility for small farmers and their access to commercial inputs
3. efforts to regroup small pump units into larger irrigation units in order to economise on the cost of irrigation, along with a clear rate for water use

RECOMMENDATIONS

The achievement of food security in common-bean production in Sudan could be attained if the following recommendations were observed:

1. The effective introduction of improved agronomic practices could be enhanced by fully involving women where appropriate in introducing improved bean varieties that are high yielding, more drought and disease resistant, early maturing, and have lower labour requirements.

2. There should be a mandate to support women farmers in bean production to alleviate food crises in Sudan.
3. Attention should be focussed on women in research, extension, and improved technologies to help increase production and, thus, food security. Extension services should be available for all women, and training programmes should be organised for women farmers to upgrade their working knowledge of common-bean production and to help increase production and, thus, food security in Africa.

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SESSION 9
RESEARCH STRATEGIES

SHIFTING FROM PRODUCTION TO MARKET-LED RESEARCH IN SUB-SAHARAN AFRICA: THE CASE OF ECABREN

Mukishi M. Pyndji

ABSTRACT

Overcoming production constraints in order to increase bean productivity in Sub-Saharan African countries has dominated bean research in the ASARECA and SADC regions for the past 15 years. In several countries, bean researchers rarely look at the needs of clients, with resulting failures in adoption that are mainly due to a focus on product instead of considering the customer first. Donor institutions wanted ASARECA and its commodity networks to develop a consumer focus if they really wanted to contribute to poverty alleviation and economic growth for the people of the region. In the 1990s, the Eastern and Central Africa Bean Research Network (ECABREN) made a proposal to include market issues in bean research, and after 1998, all commodity networks started shifting from a product focus to a customer focus in order to conduct market-driven research for economic sustainability and profitability. The ECABREN strategy is oriented towards market research, which helps target products and services much more accurately and profitably, and helps monitor and control the marketing process much more carefully (thereby cutting wasted effort and saving money).

RÉSUMÉ

Au cours des 15 dernières années, dans les régions correspondant au champ d'action de l'ASARECA et de la SADC, la recherche sur le haricot a eu pour principal objectif de lever les contraintes de production pour accroître la productivité du haricot en Afrique subsaharienne. Aussi, dans de nombreux pays, les chercheurs ont-ils essentiellement accordé la prédominance au produit (au détriment des clients), approche ayant souvent conduit à des échecs. Les bailleurs de fonds ont donc souhaité que l'ASARECA et ses réseaux de produits suivent une approche axée sur le consommateur afin de contribuer plus efficacement à réduire la pauvreté et à stimuler la croissance économique dans la région. Dans les années 1990, le Réseau de recherche sur le haricot en Afrique de l'Est et du Centre (ECABREN) a proposé d'inclure les questions des marchés dans la recherche sur les haricots et, à partir de 1998, tous les réseaux de produits ont abandonné la priorité axée sur le produit pour adopter celle axée sur le client dans une perspective de durabilité et de rentabilité économiques. La stratégie de recherche de l'ECABREN est orientée vers le marché afin de cibler des produits et des services de façon plus précise et rentable et d'aider à suivre et contrôler le processus de commercialisation de plus près (limitant ainsi les efforts et les dépenses inutiles).

INTRODUCTION

Production and marketing of dry beans (*Phaseolus vulgaris* L.) in Africa has been a major pre-occupation for farmers and scientists in Sub-Sahara African (SSA). Of all the constraints that have attracted the attention of scientists, among the most important are production constraints that limit the capacity of farmers to produce enough for home consumption and for sale in the local or regional market. For the last 15 years, scientists and farmers have tried—in participatory methods—to overcome the most important constraints. In some regions, where bean exports are important, market classes have become the most critical factor. In addition to production constraints, socio-economic constraints have become more relevant and agricultural research institutions have started focusing on them. It is without a doubt that the impact of research has been limited to areas where beans are important to the local economy.

Most small-scale farmers in the rural areas of developing countries live in extreme poverty, and the only way that bean scientists can contribute to the reduction of poverty and improvements in nutrition is through the development of marketable bean varieties for local, regional, and international markets. For three years now, the bean network (as with other ASARECA networks) has been engaged in market-oriented research, which

is not well understood by a number of biophysical scientists. The purpose of this talk is to explain market-led research in easy terms for scientific community gathered here, demystifying what has been considered as a taboo by scientists in the SSA region.

RESEARCH ON CONSTRAINTS TO BEAN PRODUCTION SINCE THE 1980S

Agricultural research during the colonial period involved selection and breeding of only a few varieties, mainly for export overseas. In most cases, integrated management predominantly focused on controlling rust in commercial varieties, for example. Integrated crop management, such as the use of chemical fungicides and insecticides, date of sowing, plant density, etc., advised farmers on producing a crop acceptable to Europe or local/regional markets. It is understandable that farmers at that time could provide themselves with fungicides and other inputs better than today's farmers. Since the 1980s, more production problems have been reported than before.

In fact, the most economic production constraints reported by farmers, agricultural scientists, and extension services include biotic (diseases and insect pests) and abiotic (low nitrogen and phosphorus, low soil acidity, aluminium toxicity, and drought). The most economically significant diseases have been angular leafspot, anthracnose, rust, root rot, common bacterial blight, halo blight, bean common mosaic virus (BCMV), and nematodes, while for insects, bean stem maggot, bruchids, thrips and aphids, and *Ootheca* (bean foliage beetle) have been damaging to all types of beans grown in SSA. From 1980 to 1997, hundreds of thousands of dollars have been invested in the SSA to overcome these problems. Several countries have considered characteristics such as the marketability and nutritional qualities of the selected or recommended products. The biophysical scientists in the region have become so important that at regional meetings/workshops, they are identified with the diseases or pests on which they work. For example, you can hear scientists joking:

- 'When you see Pyndji you see angular leaf spot.'
- 'When you see Buruchara you see root rots.'
- 'When you see Habtu you see rust.'
- 'When you see Fina you see common bacterial blight.'
- 'When you see Ampofo you see insects.'

Production versus market-oriented research

As discussed previously, in production-oriented research, the focus was the product: a resistant, high-yielding, acid-tolerant variety, etc. In contrast, market-oriented research puts the focus on the customer or client. It is concerned with the needs of the consumer. For example, the customer might want a large red bean variety or a fast-cooking variety for export. This focus has been forgotten by several research institutions; while several bean programmes have reported the release of dozens of bean varieties, only a few of them are used locally or regionally. To become a market-oriented research institution, ECABREN must be a *customer-focused* organisation. What does this mean? A customer-focused organisation . . .

- only develops the products its customers demand
- spends a lot of resources on marketing and customer liaison
- believes in the 'ask first, then supply' way of doing business

It is true that until now a number of scientists have not been interested in asking, or knowing, what the end users really want. This results in the loss of human, material, and financial resources without creating any impact on communities. Several institutions are now considering these aspects, which were often neglected.

What is marketing?

Economists tell us that 'marketing is for all businesses—big or small'. Marketing involves anything that helps towards making your customers more satisfied. Many people who were involved in different businesses in the past are no longer in business. We should remember that 'No satisfied customer = No business'. In fact, many people, such as farmers, bean seed companies, etc., stop growing a certain crop because they are unable to make profit with it.

Marketing is all to do with what are often referred to as the four *Ps* of marketing:

- The **Product** or service you sell
- The **Place** where it is sold and distributed.
- The **Price** of the product or service.
- How you **Promote** the product.

Marketing is the creative process of satisfying customer needs profitably and effectively; but this is not captured by biological scientists, who sometimes find socio-economists incomprehensible. In the bean-production channel, there are different groups that ECABREN members consider as potential partners in marketing bean technologies: producers, wholesalers, exporters, traders, and knowledgeable consumers.

What do we understand by market research?

Starting in 1997, *market-driven research* became almost a slogan in the ASARECA networks, and many scientists wondered what it meant because they were already breeding or selecting products that were commercialised for local, regional, and/or international markets. What, then, was lacking in their research approach?

The specialists give us a good definition of marketing research:

Market research is simply defined as the systemic collection of information on existing or potential markets, for analysis and subsequent action.

They tell us that to be successful at marketing, we need to find out what is going on in the market choice, specifically:

- identify customers' needs and wants
- understand the competition
- analyse the market dynamics (growing, shrinking)

This analysis tells us—biological scientists—that in order to be successful, we really need to interact with socio-economists when designing, planning, and implementing our projects.

Why do we need research?

We biological scientists sometimes feel distressed when we are told to conduct a market analysis before starting any research. This is important for both the researcher and the institution, as demonstrated below. Research is needed

- as an input to analysis and subsequent decision-making
- to find new markets
- to ascertain your customers' real needs
- to find out what your competition is doing, or why you are not doing well
- to establish the customer value proposition

Research helps to minimise risk, focus efforts, and maximise returns. In summary, market research helps in two key ways:

- First, it helps you target your products and services much more accurately and profitability.
- Second, it helps you monitor and control the marketing process much more carefully, thereby cutting out wasted effort and saving money.

Looking back, one could conclude that any research and development institution with the objective of contributing to poverty alleviation should apply market research for achieving social and economic impact. How does ECABREN plan to enter into market-led research?

DEVELOPING A MARKET-ORIENTED RESEARCH FRAMEWORK

When, in 1997, ECABREN first developed its proposal based on market orientation, it considered some information from various participants from different participating countries and referred to some knowledge that it had from different sources or studies. Although some reviewers found the proposal acceptable as being

market-oriented, a number of activities in the proposal were not based on market analysis. Two years later, the time came to phase out these activities and re-orient the research, based on market reality. Thus, the characterisation of bean markets in the ASARECA region was necessary for determining market potential and opportunities in order to set priorities and strategies for research.

With primary and secondary market and production information available, the network members identified market classes (bean types) in the region, market opportunities and marketing and production constraints with respect to locations in each country. The second step consisted of defining the goals, outputs, benchmarks, and research activities necessary for achieving the defined outputs.

To develop a market strategy, ECABREN considered its strategic objective and purpose. The network's strategic objective is formulated as 'increased income of farmers and household food security, especially protein availability, for rural and urban populations'. ECABREN's purpose is increased productivity and commercialisation of the common bean in the region, to be achieved through the development and adoption of sustainable production and processing technologies developed in partnership with national and international research institutions, non-research institutions, and beneficiaries.

An analysis of markets in the region showed that nine market classes for the common bean could be distinguished at either the local, regional, or international level (table 1).

Table 1. Market Classes, Where Important, Breeding Programmes, and Lead Countries

Market class	Number of countries where important			Programme	Market class	Lead country
	Domestic	Region'l	Internat'l			
Calima (20%)	7	3	2	01	Red mottled	Uganda
Large red (10%)	8	2	—	02a	Large dark red	Tanzania
Small red (20%)	9	1	—		kidney	
Brown/speckled	5	1	1	02b	Small red	Ethiopia
sugar (10%)				03a	Pinto	Kenya
White	7	1	5	03b	Sugars	DR Congo
Yellow/tan	6	2	—	03c	Carioca(evaluation)	Ethiopia
Pinto	3	—	—	04	Climbing beans	Rwanda
Black	6	—	—	05a	Snap beans – bush	Uganda
Snap beans	—	—	6	05b	Snap beans – climbing	Kenya
				06a	Navy – small white	Ethiopia
				06b	Navy – large white	Madagascar
				07	Yellow/browns	DR Congo

Besides production constraints, a cluster of market constraints were identified for the three market levels: limited quantities, lack of seed promotion, poor seed quality, packaging costs, lack of market information/skills, post-harvest handling, price fluctuations, transport, and taxation. While some of these factors are related to policy, the network could easily handle others, such as breeding for market classes in collaboration with NARS institutions based on comparative advantage (table 1).

The promotion of products developed by the research institutions is still considered very weak, and usually leads to the new technologies being neither accepted nor adopted, especially if not developed in partnership with end users. The research institutions do not always understand that advertising and promotion (as done by Coca Cola, beer companies, and other industries) could create new markets for their bean products. Few tools have been used in dissemination of technologies, and these only rarely. The lack of funds has been advanced as the reason for not promoting research technologies, relying instead on inefficient state extension services. There is a need to discuss a little bit about advertising and promotion—sometimes described by marketing experts as meaning the same thing—which are so important in disseminating the developed technologies.

Advertising

Advertising puts your message in front of potential (and actual) consumers so that they are disposed to buy from you. Why use advertising?

- Advertising can stimulate and increase short-term sales.
- It can attract customers' attention and helps to convince them to buy your product or service.
- It gives your product and your enterprise the right image.
- It can not only attract new customers but also helps keep actual (or former) customers.

In agricultural research, seed sales have been advertised in Malawi, resulting in significant impact on communities around the country. However, in many SSA countries, seed companies fail to advertise their products, leading in most cases to the failure of their enterprises.

Promotion

It is vital to tell your customers about your products. Promotion helps to create an awareness of your product. It involves informing people about your organisation and products (new technologies) and persuading them that they should come to you, not to your competitors. Promotion can be considered as the area where agricultural institutions in the region have failed. As mentioned above, this has always been explained by lack of social scientists and funds, but the consequences are that we end up with ignorance of the developed products, failure of acceptance, and lack of adoption.

Moreover, the almost complete lack of partnerships in the development of products has had a negative impact on the acceptance of the products or services. In fact, several breeders or scientists in the region who develop new technologies rarely involve end users, and some remain reluctant to involve end users in technology development and/or selection. The absence of a multi-disciplinary environment also leads to developing insufficiently packaged technology that is rejected. There is a need to promote the technology as a package. Several options for promotion have been used in different countries, resulting in wider adoption of the products, including variety, cultural practices, or cooking methods. Worldwide, tested (used) methods (which can be used individually or combined, depending on their cost effectiveness) include the following:

- advertising (TV, papers, posters, radio, videos)
- brochures and catalogues
- field days
- churches and mosques
- markets
- print media
- drama
- administrative meetings

Being market-led in practice: What is marketing?

Maintain quality/price relationship

Always listen to customer

Remember the need you are satisfying

Know your customer

Explain *benefits* not features

Talk to your customers

Involve all staff in marketing

Needs not wants

Grow your market share—profitably

CONCLUSIONS

Market research, as explained in this paper, can now be considered as demystified; it is no longer a magic potion that scientists should fear. On the contrary, it will help us to visualise appropriate markets for products that we are developing to benefit consumers, communities, scientists and their institutions. The objective of marketing is to satisfy the consumer while making a profit. The most important key for our success is the social and economic impact arising from the adoption of our products. To this end, partnerships and multi-disciplinary approaches are essential for customer-focused organisations like ECABREN.

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