Workshop Proceedings
Actes de Seminaire

Network on Bean Research in Africa
Reseau de Recherche sur le Haricot en Afrique

PROCEEDINGS OF A WORKSHOP ON

BEAN RESEARCH IN EASTERN AFRICA

MUKONO, UGANDA
22 - 25 June 1987

CIAT African Workshop Series, No.2

Edited by Roger A. Kirkby

Workshop Co-organiser: Mrs T. Sengooba

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PREFACE

This volume is the second in a new publications series that documents the findings of researchers on bean (*Phaseolus vulgaris*) in Africa. These proceedings form part of the activities of the pan-African bean research network, which serves to stimulate, focus and co-ordinate research efforts on this crop.

The network is organised by the Centro Internacional de Agricultura Tropical (CIAT) through three interdependent regional projects, for the Great Lakes region of Central Africa, for Eastern Africa and, in conjunction with SADCC, for the Southern Africa region.

Publications in this series include the proceedings of workshops held to assess the status, future needs and methodological issues of research in selected topics that constrain production or productivity of this crop in Africa. Other workshop proceedings, such as this one, take more of a geographical focus, highlighting research progress across many disciplines within a small group of countries.

Publications in this series currently comprise:

No. 1 Bean Fly Workshop, Arusha, Tanzania, 16-20 November 1986.
No. 2 Bean Research in Eastern Africa, Mukono, Uganda, 22-25 June 1986.

Support for the regional bean projects comes from the Canadian International Development Agency (CIDA), the Swiss Development Co-operation (SDC) and the United States Agency for International Development (USAID). The workshop reported here was supported by funds received from USAID and CIDA.

Further information on regional research activities on beans in Africa is available from:

Regional Co-ordinator, SADCC/CIAT Regional Programme on Beans in Southern Africa, P.O. Box 2704, Arusha, Tanzania.

Regional Co-ordinator, CIAT Regional Programme on Beans in Eastern Africa, P.O. Box 67, Debre Zeit, Ethiopia.

Coordinateur Regional, CIAT, Programme Regional pour l'Amelioration du Haricot dans la Region des Grands Lacs, B.P. 259, Butare, Rwanda.

TABLE OF CONTENTS

A C K N O W L E D G E M E N T S

The organisers wish to express their appreciation of the efforts of the many people who made possible the original workshop and these proceedings, including in particular the following:

The Hon. Robert Kitariko, Minister of Agriculture and Forestry, Uganda
Mr Osuban, Commissioner for Agriculture, Uganda.
Mrs Elizabeth Rubahaiyo, Director, Kawanda Research Station, Uganda
Dr Israel Kibirige-Sebunya, Acting Director, Kawanda Research Station, Uganda
All staff of the Uganda National Bean Programme
The Manager, Colline Hotel, Mukono, Uganda
The Agricultural Development Officer, USAID Regional Economic Development Services Office, Nairobi, Kenya
The Agricultural Development Officer, USAID, Kampala, Uganda
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OPENING ADDRESS

Hon. Robert K. Kitariko

Minister of Agriculture and Forestry, Uganda

Mr. Chairman, Representatives of CIAT and Regional Bean Programme, Participants, Observers, Invited Guests, Ladies and Gentlemen:

On behalf of the Government and people of Uganda, I embrace the honour of extending to you a cordial and fraternal welcome. We count it a privilege to be afforded the opportunity of being hosts of such a distinguished gathering, addressing an important subject in respect of "Bean Research in East Africa".

The first Regional Workshop is being held under the aegis of CIAT Regional Programme and we appreciate the kind gesture extended by CIAT in the provision of material and finances for this programme. We equally extend our gratitude to USAID for the contribution they have made for this workshop.

Uganda, right from the outset, supported the development of a Regional Bean Programme and was keen to share in the collaborative research opportunities that this programme will facilitate. It is commendable that in less than two years of the programme's existence, a number of things have been achieved. Our breeding programme is already benefitting from a diversity of beans introduced from CIAT headquarters and also from countries around us, e.g. Rwanda, Zaire, Tanzania, Burundi, Malawi, etc. Several of our research scientists have received training, and some research equipment has been received. It has enabled our scientists to have access to regional and international scientific publications, and even person-to-person contact is being facilitated through meetings like this workshop.

I have no reason to doubt that other countries under this Regional Programme are equally benefitting as much as Uganda is. However, I wish to put it to the researchers concerned that this is just the beginning, and all people are anxiously waiting for tangible results in terms of increased bean production and better quality beans. Therefore, your Research Programme should aim at removing the constraints to increased bean production. The compelling forces for increased bean production are:

1. The bean is readily available and a popular food to both the urban and the rural population in Uganda. FAO estimates our bean consumption as 29.3 kg per capita, this being one of the highest in Eastern Africa.
2. The beans being rich in protein go a long way in

supplementing the otherwise protein-deficient diets of many Ugandians.

3. The bean crop grows easily and has a short maturity period, making it very attractive for cultivation. In fact, where and when rainfall permits, this crop is grown throughout the year. Uganda devotes more land to bean cultivation than to any other grain legume crop.

4. The beans have enormous potential for expanding our export base, and already several countries have shown readiness to take our beans in exchange for other items on a counter-trade arrangement, provided we have sufficient quantities of the types of beans required.

It is estimated that *Phaseolus vulgaris* beans reached Uganda from the East African coast in the 18th century. Records indicate that most of the early introductions were made in the 1920s, and since then, there has been a steady increase in bean cultivation in this country. The area devoted to bean production in Uganda was 37,000 ha in 1920 whereas in the last decade, it has ranged between 300,000 to 400,000 ha annually.

Unfortunately, this increase in acreage has not been accompanied by increase in yields. According to FAO estimates our national bean yields are 600 kg/ha and that of other countries in his region range between 400-700 kg/ha. These are very low figures based on the fact that some other countries are recording over 1500 kg/ha as national averages. The challenge before you is to contribute towards increased bean yields, a demanding task indeed. We all realise the magnitude of the effort required and must therefore support both national and regional bean research programmes whole-heartedly.

Your objectives here this week are noble ones. All too often researchers of neighbouring countries in Eastern Africa have met outside the region or even outside Africa rather than in their own setting. Now that you are here, I trust you will not only exchange information but you will get to know one another so that future exchange of information and research materials will be greatly facilitated.

We in Uganda are privileged to have such a galaxy of experts like you at this time when our bean programme is struggling to take off after a period of shattered economy. I am sure our researchers are looking forward to your constructive contribution to the national programme especially as you are not only going to listen to the presentation of papers but also go to the fields.

As researchers, you should not lose sight of your ultimate goal of producing research findings that will benefit producers and consumers of beans. In the long term your results can be assessed mainly in terms of increased production and not in scientific papers published.

Of necessity, research is time-consuming. Let me hope that in this case, with your devotion and the support and contribution from the Regional Programme, we will be able to see tangible results within the near future.

I wish you all good deliberations, and to all our visitors, a happy stay in Uganda.

I have the honour of declaring the 1st Regional Workshop on Phaseolus Bean Research in Eastern Africa open.

BACKGROUND AND OBJECTIVES OF THE WORKSHOP

Roger A. Kirkby

CIAT Regional Programme on Beans in Eastern Africa

The Regional Programme on Beans in Eastern Africa has developed as a result of a meeting of national bean research co-ordinators, held seven years ago in Malawi, to consider the potential for this crop in Eastern, Central and Southern Africa. It has taken indeed a long time, both to find the necessary financial support to serve the principal bean producing countries of the continent and to establish the regional activities that we shall be discussing later this week.

In the case of Eastern Africa, the International Centre for Tropical Agriculture (CIAT) is especially grateful to the United States Agency for International Development (USAID) and the Canadian International Development Agency (CIDA), each of which has contributed 50 percent of the funding that enabled the regional programme to start in 1984-85.

Fortunately the days are past when agricultural researchers from neighbouring countries of this region rarely met one another, and then only at an International Centre or other distant venue. Nevertheless, research scientists working on beans cannot be accused of spending too much time at meetings, as this is the first such interdisciplinary meeting to be held for a considerable number of years. Lack of contact quickly leads to scientific isolation, especially when compounded with the poor state of research libraries constrained by a general shortage of foreign exchange for purchase.

Strengthening scientific exchange among the countries of the region is therefore the first objective of this meeting. It is timed to coincide with pod filling of the Ugandan crop, and the Ministry of Agriculture and Forestry has kindly arranged a field visit to one or two small farmers who produce beans, and to inspect trials of the national bean programme at Kawanda Research Station. We hope these visits will also stimulate and focus subsequent discussion.

It appears to me particularly appropriate that this first workshop is being held in Uganda. The importance of beans as a primary source of protein in the diet was recognised long ago by Uganda, and research here led to new varieties being adopted by small farmers even 20 years ago. The continuing commitment of the Ministry of Agriculture and Forestry to the development of this crop is seen in the considerable progress made in the past two years to rebuild a national research programme after the security problems that have afflicted Kawanda Research Station along with other institutions. All of us are further encouraged by the willingness of the Minister of open this workshop.

This workshop, as with all CIAT's regional activities, was planned in principle by the Steering Committee. The decision taken at its second meeting, held a year ago at Makerere University, Kampala, was followed up at our third meeting, in Ethiopia in March this year. Invitations went to the national bean programmes of the four countries of the Eastern Africa region: Ethiopia, Kenya, Somalia and Uganda. We are pleased to see that each country is represented by active researchers involved in the development and evaluation of technology to improve farmers' bean productivity, and we look forward to a lively interdisciplinary discussion of research progress and needs across the region.

As we all know, agroecological zones do not respect regional geographical boundaries, let alone national frontiers. We have therefore invited also representatives from the research programmes of countries immediately adjacent to this region that we call "Eastern Africa". We are pleased to have bean researchers from Rwanda and Tanzania; unfortunately, scientists form Sudan and Zaire were unable to come. Each of the other two regional bean teams are also represented here, emphasising that CIAT in practice has a single bean programme working in Africa with three subregional groupings.

National programme representatives on our Steering Committee made some specific suggestions for special topics for this first workshop. Dr Douglas Pachico, economist in CIAT's bean programme at its headquarters at Cali, Colombia, will be talking on one of those requested topics: the application of agricultural economics methods to bean improvement. We are pleased for another reason also that he could make the long journey: he will be taking over next month as Leader of CIAT's Bean Programme, and he will therefore be taking an increasing interest in the activities of that programme in Africa.

As most of you are aware, the Steering Committee is charged with the responsibility of guiding the development of the regional programme, identifying research priorities and deciding upon the utilisation of its resources to support research that is of regional significance. The deliberations of the Committee can only be as good as the perceptions of, and the advice received by, its individual members. While members of the Committee represent many years of experience gained in national research programmes, I think I can speak for all my colleagues in looking forward to some very serious discussions at this meeting on regional priorities. This meeting is not intended as an international conference, but rather a workshop out of which should come very much more than the sum of the results to be presented in the papers.

Contributed papers have been organised into sessions. These sessions focus upon country profiles of bean research and extension; assessment of bean production systems and their research needs; genetic improvement; crop protection; and agronomy. Each session is concluded by a general discussion on the topic, and chairmen are requested to guide these discussions in such a way as to identify issues and priorities which will be taken up again on the final afternoon, in a special session on regional programme activities.

In conclusion, then, the three objectives of the workshop are:

1. To promote the exchange of results and ideas among research and development specialists concerned with improvement of common bean (*Phaseolus vulgaris*) production in Eastern Africa;

2. To identify priority areas in which increased research effort would benefit the people who produce and consume beans in this region;

3. To guide the development of regional bean programme activities in support of national programmes.

35645

SESSION I: COUNTRY PROFILES

Profile of the Bean Research Programme and Its Impact on Bean Production in Uganda

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Introduction

Beans (*Phaseolus vulgaris* L.) constitute an important and a popular food, readily available throughout Uganda. This crop is a cheap source of protein and thus an important component in the diet of many Ugandans. About 400,000 ha. of beans are grown annually and this figure is exceeded only by that of staple food crops like plantain, millet, maize and cassava. Beans have been cultivated in Uganda for over a century, and records indicate that over a ten-fold increase in the area grown has been realised in the last 70 years (Dept. of Agric. Annual Reports 1920-1971; pers. comm. Dept. of Agric. Statistics Division). This increase in bean cultivation has unfortunately not been complemented by increases in yield as average outputs are stagnant at around 600 kg per ha (FAO Agricultural Statistics Reports).

Objectives

The prime objective of the national bean research programme in Uganda is to increase the production of this crop by increase in productivity. Research efforts are therefore directed to producing high yielding cultivars with resistance or tolerance to the major diseases and pests. The major diseases are common bacterial blight (*Xanthomonas phaseoli* E.F. Sm.) Dows., rust (*Uromyces appendiculatus* Pers.) Unger, anthracnose (*Colletotrichum lindemuthianum* Sacc. and Magn.) Scribner, angular leaf spot (*Phaeoisariopsis griseola* Sacc.) Ferr. and bean common mosaic virus. These five occur widely in the country. Halo blight (*Pseudomonas phaseolicola* Burk.) Dows and ascochyta blight (*Asycochyta phaseolorum* Sacc) are particularly destructive in the highland areas of the country. The pests of notable importance include the bean fly (*Ophiomyia* spp.), bean aphids (*Aphis* spp.) the leaf-eating beetles and the storage pests.

Other research efforts are concerned with producing cultivars which are well-adapted to the different ecological conditions of the country, providing integrated disease, pest and weed control technologies which are affordable by the farmers, identifying agronomic practices which will ensure maximum exploitation of the germplasm and the environmental potential thus leading to optimum production, and carrying out farming systems research in order to identify the farmers' problems and preferences and provide improved germplasm or technologies which will be acceptable and beneficial to them.

20 Years of Bean Research in Uganda

Serious research work on beans started in 1960 and was based at Kawanda Research Station. The breeder started off by building a collection from which variety Banja 2 was selected and released in the early 1960s. Banja 2 is a medium sized flat seeded bean, cream in colour with brown mottles. It was selected for its high yield (up to 1500 kg/ha), early maturity (70 days) and resistance to anthracnose. Banja 2 was not popular with the consumers because of its poor keeping quality. The sauce goes acidic overnight; the people complain. In 1968 another variety, K20, was released after a long hybridisation programme involving both local and imported cultivars. The good characters built into K20 included the large red mottled seed, field tolerance to most of the major diseases, resistance to anthracnose and angular leaf spot, good taste and high yields of up to 2000 kg per ha, under good management. K20 is widely cultivated in Uganda, especially in areas where the crop is grown for cash. K20 has been successful not only in Uganda but also in the neighbouring countries like Kenya, Tanzania and Rwanda. The weaknesses of K20 which have been gathered through informal interviews include a relatively hard testa coupled with long cooking time and its coarse leaves which make the vegetable dish unpalatable. This variety was released to the Uganda Seeds Project in the early 1970s. However, it could not meet the required standards of a seed crop mainly because of susceptibility to common bacterial blight.

Soon after the breeder started his work in 1960, a plant pathologist joined him to cater for the disease problems. The major diseases were identified (Leakey, 1970). Considerable attention was paid to bean anthracnose and the races of this fungus were established (Leakey and Simbwa-Bunnya, 1972). In the late 1970s angular leaf spot was worked on in connection with the behaviour of the fungus in culture, morphology of the causal organism, transmission, epidemiology and control of the disease (Sengooba, 1980). Several fungicidal spray trials have been carried out and resulted in significant increases in yield though varying with the variety and the disease levels.

The agronomic investigations carried out resulted in the present standing recommendations, for example, the spacing of 60 x 10 cm and planting at the beginning of the rains, March-April and August-September. These agronomic recommendations have had hardly any impact on the farmers who still plant at populations and in patterns determined by their own farm practices. The times of planting also appear to be influenced by rainfall and labour availability.

Pests and their control were studied by several workers (Rubaihayo *et al.*, 1980). Aphids were reported as a major problem, and the recommendation was to avoid them by early planting. Bruchids were found to cause considerable loss in store. The recommendation provided was to dress seeds with malathion dust 2%. This is observed only by some people who handle beans on a commercial scale.

Uganda Bean Programme in the 1980s

The 1980s found the programme in a desperate situation with no improved cultivar acceptable for seed multiplication by the Government Seed Multiplication Project and therefore a demand for one. The promising materials that would be in the pipeline had not received sufficient multilocational testing due to lack of funds and facilities. The situation was worsened by the departure of the two breeders on the programme and above all by loss of germplasm, equipment, literature and data during the 1985-86 war period.

On the other hand, it was in 1980 that the initial contacts between the Ugandan bean researchers and the CIAT international bean research programme were made. It is because of this contact and the support and benefits derived from CIAT headquarters itself and from the CIAT Eastern Africa Regional Bean Programme that the Uganda bean programme exists today with reasonable strength.

The research activities on beans have bean decentralised from Kawanda Research Station to two other locations 2 ems Kackwekano District Farm Institute in south-west Uganda and Serere Research Station in eastern Uganda. Research scientists were placed at these sites and work started at Kackwekano and Serere during the first seasons of 1986 and 1987 respectively. Kackwekano was selected as a site for bean research because it is different from Kawanda in altitude, being 2250m while Kawanda is 1300m, and south west Uganda is the most important bean-growing region of the country. Serere was chosen because it is an area drier than Kawanda and the basic infrastructure and research facilities were available. Kawanda is the main primary screening site but materials introduced or bred specifically for high altitude adaptation or for drought tolerance are primarly evaluated at Kachwekano and Serere respectively.

Under the present circumstances where germplasm is being reassembled and yet there is an urgent need to identify cultivars for release, the main activity of the national bean programme has to be evaluation of materials. The materials being evaluated are those which have been introduced from CIAT headquarters in Colombia, from several African countries through the arrangements and support of the Eastern Africa CIAT Regional Bean Programme and those collected locally from within Uganda in the recent past. An evaluation sequence, consisting of six stages, has been established. The stages in this sequence include a first and a second screening nursery in which adaptation is emphasised but disease resistance is also considered. Screening against the major diseases, pests and environmental factors follows at three or four locations. The third stage is the preliminary yield trial followed by multilocational testing at some twelve sites scattered all over the country. On-farm evaluation will be carried out at the same time as the multilocational trials.

The materials at the first screening stage amount to over 2000 lines and include 1200 germplasm accessions recently obtained from CIAT headquarters and known to represent the types of materials available in the CIAT germplasm bank; the CIAT 1986 'VEF' nursery with 866 entries; over 100 introductions from Rwanda, seven introductions from Kenya and about 62 local materials recently collected from eastern Uganda.

At the second evaluation stage there are 59 re-introductions from CIAT headquarters. These are materials which had been found to do well in Uganda previously but were lost during the looting in 1985. There are also seven introductions from Morogoro, Tanzania. There is a "climbing red" and "true climbers" IBYAN nursery each with twelve entries, presently being evaluated at Kachwekano.

The third stage of evaluation is largely that of disease nurseries. There are 160 and 60 entries in the rust and the common bacterial blight nurseries respectively at Kawanda. The other disease nurseries being grown are the international common bacterial blight and the halo blight ones recently received from CIAT headquarters. Other nurseries to be established in the near future include the ascochyta blight nursery, the anthracnose and the bean fly nurseries.

The materials in the preliminary yield trial include those in the "AFBYAN" which is a regional trial presently being grown at four locations in Uganda, the promising lines from the earlier (1981) introduced CIAT materials and some land races altogether amounting to over 50 cultivars under evaluation at this stage.

The multilocational trials are to start during the second season of 1987 with the materials that will be selected out from the preliminary yield trials. On-farm testing may start at the same time or during the first season of 1988.

In addition to evaluation of materials, the Uganda bean programme is engaged in research under the disciplines of breeding, pathology, agronomy and soil science. The breeding projects include those on breeding beans for rust resistance, and under this project attempts are being made to incorporate rust resistance into the high yielding K20. A project on breeding beans for resistance to common bacterial blight is in its initial stages, and under this proposal it is planned to develop a common bacterial blight nursery within the Eastern Africa region as well as develop resistant cultivars. Studies on the breeding and pathology of ascochyta blight have been initiated, and this proposal is also to be carried out at a regional level. The other breeding projects include those on breeding beans for halo blight and anthracnose resistance. Evaluation for better nitrogen fixation and improving some land races with respect to yield as well as pest and disease resistance without changing palatability and cooking qualities are also activities under the breeding discipline.

All notable diseases are considered during material evaluation exercises, but specific pathological research is done on the bacterial blights, anthracnose, rust and ascochyta blight. The studies on these diseases are mainly designed to complement the breeding efforts. Disease crop loss studies based mainly on the popular cultivars and land races have been recently started. On-farm and on-station trials designed to study disease levels in beans grown in monoculture and in association with potatoes and under bananas is to start during the second season of 1987, and baseline data to aid in what patterns can be used has been collected.

The bean agronomy work is starting off after a long break with emphasis on on-farm investigations. Diagnostic surveys have been accomplished in three bean producing areas. Studies are also underway on mixed cropping and weed control.

Personnel

The bean programme is run by a centrally co-ordinated multi-disciplinary research team composed of three breeders, two pathologists, two agronomists, one entomologist and one soil scientist.

Research on Beans at Makerere University

At all times efforts are made to ensure that the research on beans carried out at Makerere University is complementary to rather than a duplication of what is done in the Research Division. The cultivar Kabanima is a product of the Makerere bean project. Kabanima was never officially released in Uganda but is one of the top cultivars in Tanzania.

In the 1970s Makerere ran a programme on improving Mexican 142 for seed protein and yield increase through hybridisation and induced mutation. Superior lines were obtained, but unfortunately these lines were susceptible to common bacterial blight. Presently, efforts are concentrated on virus diseases, in particular common bean mosaic virus.

Main Constraints

Shortage of Money:

The funds obtainable from the government are not sufficient to run the programme. What is requested in the annual estimates is never all approved. The amount approved is not all released. The amount released comes out sporadically. All these factors make planning difficult and proper flow of activities in the programme impossible. Many required items cannot be bought because of this lack of funds.

Lack of Transport:

The programme has access to only one vehicle, the Regional Programme vehicle, and this is not enough for a national programme operating at three stations with multilocational and on-farm trials.

Future Plans

1. To ensure continued flow of materials through the evaluation sequence so that improved cultivars will be released periodically.
2. To standardise the evaluation techniques including innoculation methodologies for diseases and pests and routinely testing promising materials in the disease and pest nurseries.
3. Study the genetics of cooking time and taste in beans and establish how transferable these characteristics are within bean cultivars.
4. To acquire facilities to support an efficient and fast moving hybridisation programme so that the Ugandan breeders are able to shoulder the "crossing" work which for the time being is done for them at CIAT headquarters.
5. Strengthen the national programme by building up manpower at the stations of Kachwekano and Serere and also strengthen on-farm research.
6. Continue searching for and utilising all training

opportunities ranging from short courses to doctorate degrees and thus continue building up research capabilities.

Conclusion

Research on beans has been done for a long time in Uganda. The success of K20 indicates that when a good variety is produced it is taken on quickly and widely. The agronomic practices recommended in the past have hardly had an impact on the farmers' practices and this appears to be because the recommendations were not applicable under the given conditions. The programme has suffered a lag through the 1970s up to 1986 due to problems centred on poor funding and political instability. The bean programme therefore in a way started afresh in 1986. However, already the Uganda Seeds Project is asking for an improved cultivar for multiplication with a budget and targets already set. The Uganda government has export commitments based on bartering beans for other needed commodities in the country. The farmers would also be very happy to receive improved cultivars as they have not had any new bean from the Research Division for the last 19 years. The situation is therefore desperate but with the support and interest shown by the Uganda government in the programme and the existing collaborative efforts with the CIAT bean programmes, solutions are forthcoming especially if the constraints facing the programme presently are minimised.

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Makerere University's Role in Regional Research on Beans In Africa

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Introduction

In 1960 breeding and improvement programmes for beans and groundnuts were started at Kawanda and Serere Research Stations respectively (Leakey, 1970). The initiation of the bean programme was prompted by the 1959 recommendation of the World Health Organisation's Food and Nutrition Conference that work should begin on pulse crop improvement in order to avail the people of abundant plant protein (Leakey, 1970). The bean improvement programme was further stimulated by the recommendation of the 1961 meeting of the East African Specialist Committee for Agricultural Botany (SCAB) that "a detailed study be made within each of the East African territories of the distribution of the major food legumes, the types grown and their role under each farming system." And that such improvement programmes should consider "the protein composition and palatability of edible seed" (Leakey, 1972).

The nutritional concern became topical because it had been revealed that the per capita consumption of animal protein in Uganda was only 20 grams instead of the recommended 85 grams (see Nyankori, 1971) and hence the need to complement it with a cheaper plant protein source. Secondly, there was a methionine deficiency of the order of 20 despite the preponderance of grain legumes in the local diet (McDowell, 1972). Consequently, bean improvement programmes such as those at Kawanda Research Station and Makerere University Farm, Kabanyolo, were geared to improving protein and methionine content as well as yield and disease resistance (Leakey, 1971)

In spite of the SCAB recommendation that the role of beans in each farming system be considered, little or no consideration was given to the needs, problems and opportunities of local producers and consumers in designing the improvement programme. There, there was a need to provide more and better quality plant protein, but in what context? In any case, what were the root causes of low levels of availability and consumption of beans?

Given the limited domestic and export markets for beans, could a pursuit of a reduction in post-harvest losses rather than productivity gains, if combined with breeding for insect and disease resistance, have been a more cost-effective method of addressing the problem of malnutrition? To what extent could the habit of using insects, wild animals and birds as food by local people have resulted in an exaggeration of the reported protein and methionine deficiency? How have bean cooking methods used by the local people affected the ultimate quality of the ingested protein? How have the existing patterns of resource allocation and cropping systems by household influenced the production of beans? What have been the tastes and preferences of consumers?

Considerations of these questions could substantially modify the objectives of the bean improvement programme if indeed the smallholder producers are the target group. Surely, operating in a situation dominated by mixed cropping under conditions of seasonal labour constraints and poor marketing infrastructure, the research scientist should consider the returns to labour and the efficacy of mixed cropping as opposed to the generally recommended monocultures.

Research on mixed cropping, however, began ten years after the initiation of the bean improvement programme and it was restricted to Makerere University Farm, Kabanyolo (Wiley and Osiru, 1972; Osiru and Wiley, 1972). Yet research benefits of multilines in minimising disease damage had already pointed to possibilities of similar benefits being provided by mixtures (Van der Plank, 1963; Borloug, 1959). Even in the Makerere mixed cropping trials, no attempts were made to closely emulate the cultivars' practice so that cost comparisons could be made between what has been found to be more productive and the farmers' practice. This aspect is important because more recent findings from elsewhere (Kenya) have indicated that there is a possibility of cultivators incurring losses in return to labour (to the tune of ca. 73%) if they shifted from a system of mixed cropping that is very close to the traditional pattern to that recommended by researchers on the basis of higher yield gains (Gathee, 1982).

In general cost considerations were ignored by research scientists involved in the bean improvement programme in Uganda. A simple case in point was the use of fertilisers on beans where it was recommended that a split application of nitrogen be made: the first at sowing and the second three weeks after sowing (Hughes, 1971). But given the common cash-flow problems among smallholders, poor storage facilities, stiff competition for labour between beans and other crops in the season as well as leisure and the likely possibility of late planting, one wonders whether real opportunity costs of implementing that practice would not have been of interest to a research scientist wanting to see the recommendations widely adopted by the local bean producers.

Entomological research efforts devoted to bean and other subsistence crops have been minimal and have tended to be largely incidental. Research continued to be a hobby-type of affair until the 1950s, when vigorous investigations especially on bean breeding began. However, despite numerous references to the importance of insect pest to bean production in Africa in general, the mandates of such breeding programmes have never explicitly or deliberately incorporated breeding for insect resistance, nor were impacts of insect pests quantitatively assessed. Because of this, it is rather difficult to discuss conclusively the economic status of these pests in relation to bean production in any of the East African states. Research on bean diseases started in 1960 (at Kawanda Research Station) and 1965 (at University Farm, Kabanyolo) with major emphasis on disease resistance. The bulk of the work concentrated on the devastating impact of diseases and pests on yield. These were much more easily recognised than those of viruses. There was general lack of awareness of the widespread prevalence of bean viruses and their potential for chronic yield depressions.

Outlook

Focussing into the future, three main possible collaborative projects with major inputs from Makerere University can be identified.

Existing Socio-Economic Project

The importance of understanding farmer circumstances has been recognised, though in passing, by some biological scientists involved in bean improvement in Uganda. For instance, Leakey (one of the early workers) accepted the validity of the common criticism in Uganda that some of the advice on how to obtain higher yields of food crops did not make it clear whether such increased yields could necessarily be economically attained when allowance was made for the costs of materials and time involved. While accepting the importance of cost data relevant to the technical research worker, Leakey, however, rightly expected such data to be provided by economists and sociologists.

Indeed, studies by Makerere University economists had already suggested that labour and not land limited production and that although surplus production capacity of labour clearly existed, the returns for producing established food crops such as beans for sale were not sufficiently attractive to draw out that potential. Similarly, it has been argued that producer responses to new varieties of beans which give much higher yields depend largely on the return to labour. It is therefore regrettable that this critical coefficient is not usually calculated by research scientists.

The need for collaboration between social and biological scientists in a bean improvement programme, therefore, is influential. In Makerere University, the Faculty of Agriculture and Forestry has established a Farming Systems Research (FSR) Group to foster interdisciplinary collaboration. Most members of the group have been trained in FSR techniques under the auspices of CIMMYT Eastern Africa Programme which is likely to support a Makerere project on improving the productivity of limited resources in selected farming systems of Uganda. There exists a good potential for collaboration between Makerere FSR Group and the national bean improvement programme.

Insect Pest Research and Control Efforts

One inescapable fact about insect pests of beans in East Africa is that this crop is attacked by many insects whose relative economic impact on bean production is not fully known. It is also a fact that the majority of the major insect pests attacking beans within the region are extremely polyphagous (e.g. *H. armigera, A. horrida, A. tomentosicollis, N. viridula*, thrips, aphids).

Polyphagy has important implications both in reference to research and control efforts. For example, many insects change their biologies with corresponding change of diets. Host (insect)-natural enemy relationships will also vary with the host-plants upon which the insect-hosts feed. Economically and biologically, it is more difficult to successfully manage the populations of polyphagous insect pests using conventional control methods such as chemicals because of acquired differential diets. Polyphagy thus becomes highly relevant in the context of the current (or envisaged) small-holder bean production systems where over 90% of the total bean production is carried out under mixed cropping systems. Most traditional crops mixed with beans are alternate host-plants of the bean pests. This certainly is an area where entomologists should take the lead when designing studies to minimise pest problems in smallholdings.

For some past studies in East Africa, the implications of the polyphagy phenomenon were never realised, although Coaker (1960) had earlier shown the importance of this phenomenon in respect of *H. armigera* in Uganda which was again recently observed by Materu (1971) in the study of population dynamics of *A. horrida* and *A. tomentosicollis* in Tanzania. Materu demonstrated that *A. horrida* and *A. tomentosicollis* maintained themselves throughout the year by changing host-plants from beans to pigeon pea to *Dolichos lablab* and black beans.

Similarly, another area of bean entomology that has been grossly neglected is the storage pest problems. Doubtless, the importance of storage pests has not been appreciated largely because the damage done is not spectacular. It is of an insidious nature and is not often detected until the commodity (beans) is about to be consumed or sold, and yet storage losses are often of the same order of magnitude, or if not, higher than those sustained during the cultivation of beans. Studies on the use of chemicals to control storage pests in Uganda were relatively more advanced but have since stopped. Oil treatments for protection against *Acanthoscelides obtectus* and *Zabrotes subfasciatus* were recently assessed in Kenya. Results showed amounts of oil required ranged from 2-15 cc/kg seed, depending on the degree of infestation. Side effects and alternatives for oil treatments have also been discussed.

Specific work on the biology and ecology of some of the field pests of beans in East Africa lack detail of economic analyses of the subject pests but do give comprehensive biological detail which hitherto has not existed. For example, it is now known that plant populations and production systems can affect the biology of the bean insect pests, as the work of Karel and Matary (1983) shows. These authors studied the populations of some major bean pests under four combinations and clearly showed that *Ootheca bennigseni* damage was higher in the inter-cropped beans than in monoculture and that the incidence of *T. sjostedti* was low in pure stand. *H.armigera* population was higher in pure stand than in the intercropped beans whereas the larval population of *M. testulalis* remained generally low in both pure and intercopped stands of beans. Incidentally, these same pest species more or less showed similar infestation patterns when attacking cowpea crops grown in mixtures with maize. Greathead (1968) has also demonstrated that among the beanfly complex, only *Ophiomyia spencerella* is of significance in the bean production in East Africa. Damage by *A. horrida* and *A. tomentosicollis* is now known to result in the reduction of weight, number and quality of seeds. Quality reduction is sustained irrespective of the population levels of these insect pests.

Approaches to control field pests of beans within the East African region have included a combination of cultural practices, insecticides and planting of resistant bean varieties.

Adjustments of planting dates in Tanzania indicated that the most reliable time for bean sowing to combat *O. bennigsensi* is from late March to April 17th, while aerial sprays of DDT consistently show a marked degree of effectiveness in controlling damaging populations of *H. armigera* and *A. horrida* in pure stands of beans in Tanzania. Differential reaction of bean varieties to insect attacks have been evaluated in Tanzania as well. None of the 27 varieties tested showed total immunity to *O. bennigseni* attack, although significant varietal differences in feeding were recorded for this pest. This finding clearly shows the importance of insect pests in any undertaking of bean production improvement programmes.

Biological control attempts of field pests of beans are almost non-existent although records by Greathead (1968), Nyiira (1970) and Robertson (1973) show that there were important larval parasites of some of the major bean pests within East Africa. Robertson recorded 37 species of primary parasitoids attacking ten lepidolteran caterpillars. A number of these parasitoids show marked degrees of polyphagy. Greathead (1968) believes that *Ophiomyia phaseoli* and *O. centrosematis* (both Agromyzids) are largely controlled by their habitual parasitoids, one of which, *Opius melanagromyzae*, was recently shipped to Hawaii for release against *O. phaseoli*. Epidemiological appraisal has preliminarily shown promising potential of these parasitoids in the Hawaiian environment. Eight parasitoids and nine predators attack *H. armigera* in Uganda and as speculated by Nyiira (1970), further exploration for natural enemies of lepidoptera larvae attacking beans and the study of their efficiency may lead to significant reduction in the costs of control measures in general. This is yet another area where Makerere University personnel resources could be utilised to benefit regional programmes.

Bean Virology

In development programmes for bean crop improvements in Africa, there is generally a lack of awareness of the widespread prevalence of bean viruses (at least sixteen different viruses are known). Because of the overwhelming importance attached to fungi and bacteria, it is not uncommon to find scarce information on viruses infecting many agricultural crops in African countries. This may be partly due to lack of trained virologists or general lack of interest. We in Makerere University, working on beans, have decided to focus our research efforts on distribution and importance of bean common mosaic virus (BCMV) in Uganda because we believe that the chronic 20-50% potential loss due to BCMV in Africa is so unnecessary and can be easily cured by breeding. We have decided to take a leading position in this area in order to make information on pathotypes available so that our plant breeders will in future be able to reliably screen their segregating hybrid populations to the correct pathotypes.

Working with 63 landraces, we have up to this time been able to demonstrate the presence of seed-transmitted BCMV of serotype A and B in Uganda. Infected tissues were tested for BCMV using antisera NL-3 and NY15. When infected bean tissues from cultivar "Mudugabo" were saturated in a small volume of 0.1M PO4 pH 7 (giving a concentration of virus extract = 1 gram/10 ml and an aliquok coated on 300 mesh copper grids with carbon fronted forvar (0.35%), 15 minutes later BCMV particles could easily be seen from this tissue preparation in electron microscopy at 8,000 X magnification. These findings have significance for future breeding work in Uganda and other African countries, and they also open opportunities for bean scientists in these countries to do biological confirmation studies to identify the most frequent and virulent strains of BCMV in our countries.

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35646

Bean Production and Research in Ethiopia

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Importance of Beans in Ethiopia:

In many low lands of Ethiopia, haricot bean (*Phaseolus vulgaris*) is considered as the main cash crop and protein source of the farmers. It is also an important export commodity of the country. In production and acreage it is the fifth most important pulse. In the 1983/84 cropping seasons a total of 37,146 ha of land was in bean production, and the average yield was estimated to be 658 kg/ha (MOA, 1985). Central Ethiopia (Shoa) was the highest bean producer followed by Sidamo, Harrarghe and Wollega, with the dry seed production of 9066, 4432, 3289 and 3248 tonnes respectively (MOA, 1985).

The Rift Valley areas, in central Ethiopia, are the main bean producing zones, where white pea beans are important for export market. In eastern Ethiopia, (Harbo, Chercher and Harar Zuria) beans of various seed colours are grown mainly for local use. In southern Ethiopia (Sidamo and Gamo Gofa) red-coloured flat-shaped, medium-sized beans are very important in the daily diet of the people. A climbing type of bean with large seeds is preferred in Wollega where the people consume it as green beans.

Most of the beans are grown by peasants who do not have enough inputs such as fertilizer, improved varieties etc., and as a result the national average yield is low. To improve the yield of beans in Ethiopia, the Institute of Agricultural Research (IAR) established the Bean National Research Programme in 1972, centred at Nazreth (Ohlander, 1980). In 1980 team approach research work was started, and now the bean research is done by a team composed of different disciplines. Improved varieties are released and the best bean production areas are identified.

Bean Crop Environment

Ethiopia lies between latitude 3^{o} and 18^{o} N and has a wide range of altitude (Map 1). Such differences in altitude create various agro-ecological zones with different patterns and amounts of rainfall. Minimum and maximum temperatures are also highly influenced by the elevation.

Results of the National Variety Trials conducted at different agro-ecological zones at different years showed that some areas are more favourable than others. The suitable areas for bean production using present technology can be described as follows (Ohlander, 1980).

Altitude:	1400 - 2000 m for rainfed conditions and $\geq$ 700 m for irrigation production.
Rainfall:	Well-distributed rainfall of 350 - 550 mm for over 70 to 90 days depending on altitude.
Humidity:	Relative humidity should not be very high; not above 75%; however, the effect of relative humidity is also correlated to temperature.
Temperature:	Mean maximum < 30 - 32°C Mean minimum > 10 - 12°C

Bean Production Systems

Most of the cultivated land in Ethiopia is on small subsistence farms. Recently, large acreages of government-owned farms have been started. Traditionally, small farmers grow beans on poor soils or on lands that have been depleted of essential nutrients after long years of planting with cereals. The belief of the farmers is that beans can renew the poor soil. Scientifically it is proved that legumes can fix atmospheric nitrogen and make it available in the soil after they are harvested. Under Ethiopian soil conditions, a few inoculation trials have been conducted and the result showed that beans could fix up to 18 kg/ha N which was not enough to support growth and development (Abebe and Abegaz, 1982). On the other hand nitrogen fertiliser trials indicated that beans do not respond to nitrogen (Ohlander, 1980). The findings of inoculation and N-fertiliser trials are not in harmony, and that needs further investigation.

Pure cropping is the most predominant of bean production systems in most lowlands. In some areas where rainfall is sufficient farmers grow beans intercropped with maize, sorghum and other cereals. Usually beans are grown under rainfed conditions; however, research findings indicated that a high yield of about 380 kg/ha of seed could be harvested by using irrigation in the area where the altitude is low ($\geq$ 700 m above sea level) (IAR, 1975, 1976).

The land preparation for bean planting varies from place to place. In most areas two ploughings are used to grow beans, and in some locations more than two ploughings are common. However, beans received less ploughing and land preparation than other cereals. After land preparation or ploughing (usually done by a pair of oxen using the local plough called "Maresha" which consists of a bent wooden beam with a narrow iron point to break or crumble the soil), beans are normally broadcast at the rate of about 72 kg/ha of seed by hand and covered with one ploughing.

The normal planting time of beans during the main season is from June to July in most lowlands. In some areas beans are also planted from February to March during the small rain periods, "Belg". In Awash areas (altitude 700 m above sea level) beans can grow successfully by using irrigation, and the planting period is October to November. In general, for bean production under rainfed conditions, early planting is good in the lowlands with three months of rainfall. In the areas of less rainfall, planting could be done in such a way that the crop would mature and be ready for harvest in dry weather at the end of the rains.

Beans are seldom weeded by small farmers in the Rift Valley. Weeding is usually done by hand. Farmers do not use chemicals to control weeds, for they can't get them. Bean yield losses due to weeds in the farmer's field are estimated to be quite high, more than 50%.

Harvesting of beans is done by hand-picking of the whole plants and rarely with sickles. Threshing is by animals, and in some cases, where the harvest is very small or animals are not available, hand threshing using sticks is practical.

Farmers store their beans in containers made of clay soil or in sacks until marketed. There is a high loss of beans due to damage by store insects. It is difficult for farmers to store their seed more than a year.

Factors Limiting Bean Production

There are many constraints to bean production in Ethiopia. Some of these are:

1. Poor cultural practices used by farmers.

2. Lack of suitable varieties for different agro-ecological zones.

3. The price of beans is not stable; sometimes it receives a much lower price than cereals.

4. Diseases such as rust, anthracnose virus and bacterial blight are important.

5. Insects such as African bollworm and bean fly are limiting factors in some areas.

Bean Research Programme in Ethiopia

A co-ordinated research programme was started in 1972 by the Institute of Agricultural Research (IAR). Since then four beans varieties have been released to the producers. The varieties are Mexican 142, Black Dessie, Red Wollamo and Brown Speckled. Mexican 142 is a white pea bean type and now is used for commercial business. Brown Speckled and Red Wollamo are local selections grown for local consumption. Black Dessie is highyielding and resistant to many bean diseases; however, because of its black seed colour, it has not been accepted by many users.

From 1980 the research programme was organised by the team approach method. The team consists of different disciplines: breeding, agronomy, soil science, entomology, pathology, weed science, food science and socio-economics. Not much work was done in food science because of lack of scientists in that field. The other disciplines will present their findings in this meeting during the following days.

The breeding programme of haricot bean is a team effort. The programme starts with materials from different sources. Their adaptability is tested at three different agro-ecological zones. The three locations for nursery I (first screening nursery) are:

1. Awassa (medium altitude, 1700 m above sea level) with high rainfall,

2. Melkassa (1500 m above sea level with low rainfall),

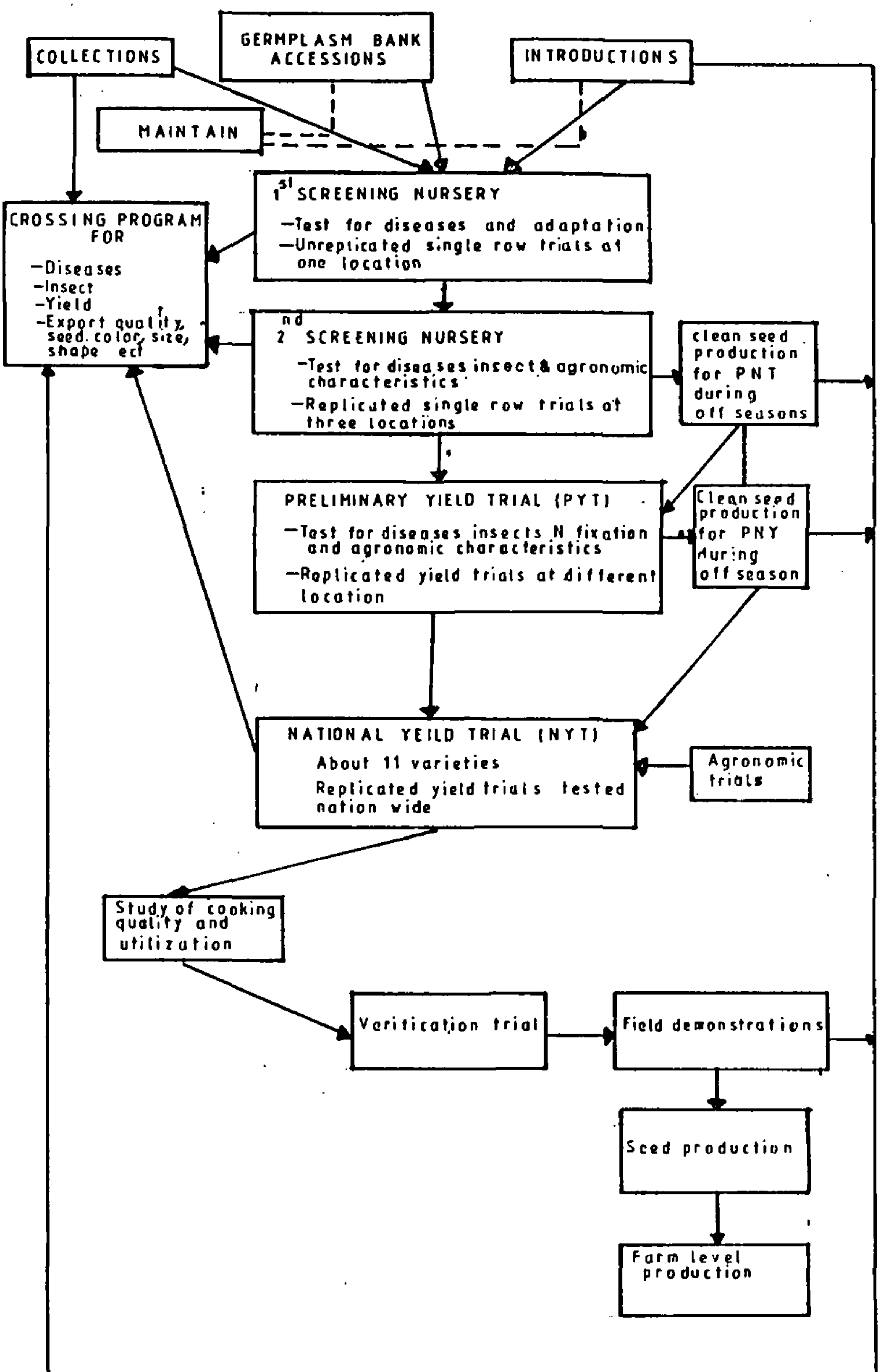
3. Pawe (1200 m above sea level with high rainfall).

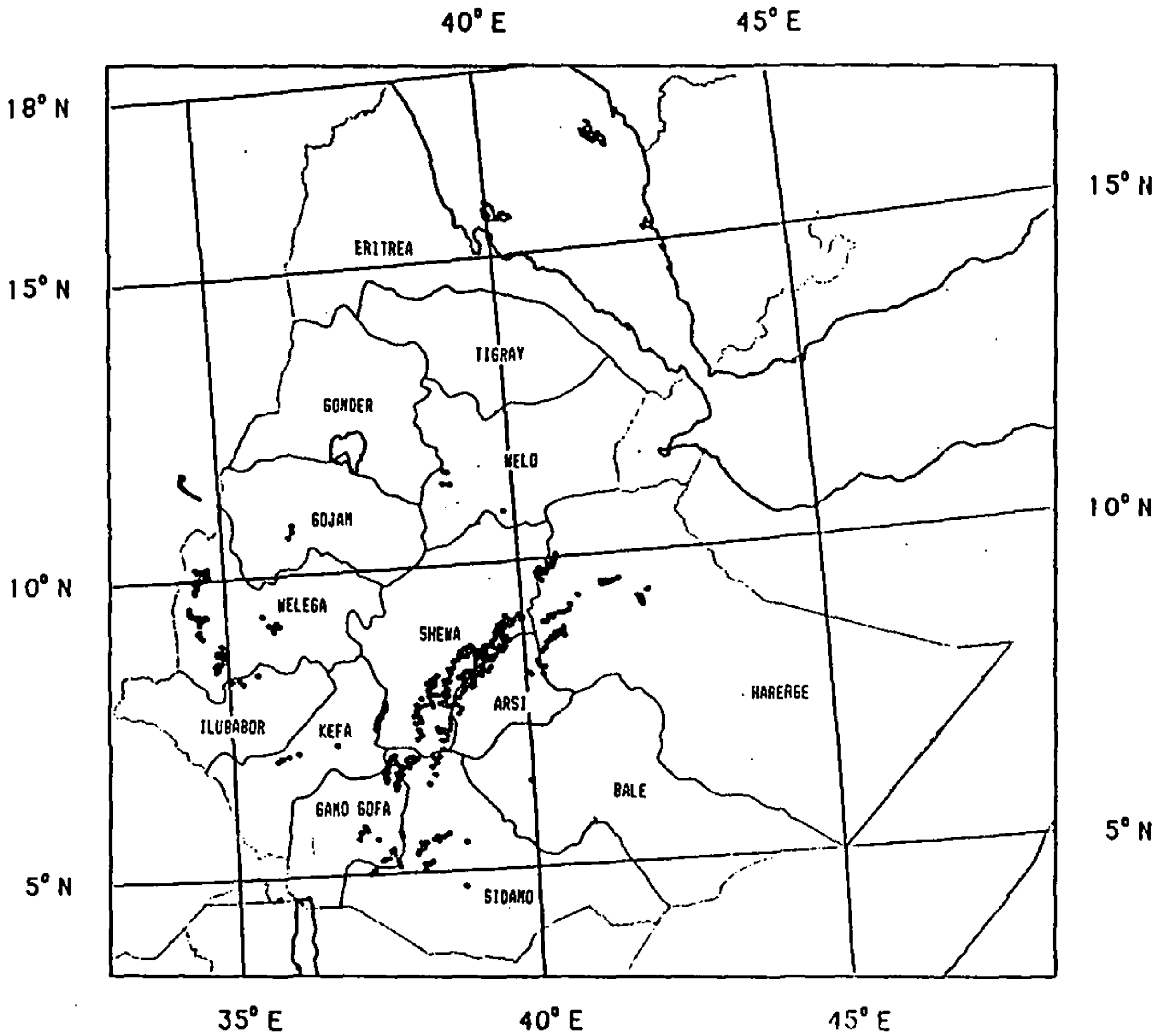
Those entries with good performance in the first screening nursery will be promoted to an advanced nursery and so on (Fig. 1). As a result of the breeding programme, top yielding varieties across different locations will be released to the user after approval of the release committee. Now there are four varieties ready to be released and they are on verification trial in farmers' fields. These varieties are W-117 (0150-1), 6R-395-08, W-108(0177-2) and W-95-08.

Acknowledgements

I gratefully acknowledge IFS for sponsoring me to present this paper in this meeting. Due thanks is also extended to CIAT for organising such a workshop to let the Eastern African bean researchers exchange their findings.

Figure 1. SCHEMATIC DIAGRAM OF *Phaseolus vulgaris* BREEDING PROGRAM.





Map 1. Principal Bean Producing Areas of Ethiopia

Source: CIAT Agroecology Unit, from data provided by Ministry of Agriculture (1983-84).

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Grain Legumes in Somalia

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Introduction

The Somali Democratic Republic is situated in the Horn of Africa. It lies between latitudes 12° 0 N and 1° 35 S. The total area is 638,000 square km of which 8.2 million ha are suitable for cultivation; 28.8 million ha are used for livestock raising and the rest is non-agricultural land.

There are two rivers in the country: the Juba and Shabelle. The length of the Juba is 800 km and that of the Shabelle is 1100km. Their catchment areas are 275,000 sq km for the Juba and 300,000 sq km for the Shabelle. The average annual flow of the Juba is 6 billion cubic metres while that of the Shabelle is 2 billion cubic metres.

Somalia, being situated on the equator, has an arid and warm climate with average daily temperatures ranging from 25°C to 35°C. The average annual rainfall is less than 600 mm in most of the country. Only the inter-riverine areas receive more than 600 mm. There are two rainy seasons, namely Gu (April - June) and Der (October - November). In addition, the country's southern coast gets rain also during Haga (July - August). The wettest month is June with an average precipitation of 97 mm. The humidity in the country varies from 63% in the dry season to 82% in the wet season.

The population was estimated in 1983 to be around 5.2 million, of which 46% are nomads, 29% are settled people (mostly farmers) in the rural areas, and 25% are urban dwellers.

Agriculture is the second largest part of the Somali economy, and a large part of the population is involved in agricultural activities. Estimates of production of a number of major crops is given in the table below.

Grain Legume Crops

The most important grain legume crop in Somalia, with respect to both area and production, is cowpea. An estimate of area under grain legumes in 1986 was over 32,000 ha. Cowpea alone occupies almost 75% of the total area under grain legumes.

Table 1. Agricultural Production in Somalia (000 tonnes).

Crop	1978	1979	1980	1981	1982	1983
Sorghum	141	140	140	222	235	120
Maize	107	108	110	142	150	235
Rice	12	13	17	19	20	3
Beans/cowpeas	10	8	9	13	15	21
Sesame	40	41	38	53	57	60
Groundnuts	3	3	3	4	3	3
Cotton	4	8	0	3	5	4
Sugar cane	312	261	420	500	535	500
Bananas	70	72	60	69	72	85
Other fruits and vegetables	28	27	27	35	102	83

Source: Ministry of Agriculture

Cowpea is cultivated twice a year, from April - June with an average rainfall of 350 - 400 mm, and from October to December with an average rainfall of 200 - 250 mm. Cowpea is popular because of its tolerance to drought. Over 90% of cowpea is produced by traditional farmers with small holdings ranging from 3-3.5 ha. All cowpea produced in Somalia is consumed locally. Usually the cowpea crop is neither sprayed nor fertilised; consequently, the yields obtained are relatively low.

Harvesting and Storage

Generally harvesting is done when pods are dry. During the dry period while pods are still on the plant, they are attacked by birds, rodents and pests which cause severe damage. Similarly, a notable quantity of the produce is lost in crop disease before harvesting. Before coming to pod, the crop is already infested by various species of Coleoptera which lay eggs on pods. Although this infestation in the field is not very severe it will be the potential source of infestation when seeds are stored. The estimated losses vary from 2.3% to over 50%. Studies done in two districts of the region of the lower Shabelle specified damage caused by insects was 3% to 31% for Jowhar, 1% to 61% for Marea and 0 to 46% for Afgoi.

Storage is essential whether it is for seed or for consumption. For farmers, it is difficult to preserve their produce effectively so they bring it to the market. In this way they lose seeds for planting the next season, and prices are depressed. One of the traditional ways for preserving produce was the use of smoke. By building a platform store above the ground, beans and were smoked and heated by a fire under the frame. This technique keeps insects away from the stored product.

Grain Legume Improvement

Insect pests and diseases are the main limiting factors leading to low yields of 200 to 300 kg/ha against over 1500 kg/ha on experimental plots. One of the main research objectives is to optimise cowpea yields by using pest- and disease-resistant cultivars which experience early maturity, are well adapted to local conditions and are acceptable to local consumers.

The breeding programmes of research concentrate on improving and introducing varieties as well as sorting for grain legumes. In Somalia two major grain legumes are grown: Cowpea and mungbean. Both of these crops constitute remarkable and valuable sources of protein in the diets of small farmers and the whole of Somalia. They are also valuable as animal fodder. The cultivation of these two crops and especially of cowpea is done throughout the southern part of Somalia.

Cowpea grows well under both irrigation and rainfall conditions. The crop is grown by small farmers using their primitive traditional production practices resulting in low yields. Research efforts have concentrated on cowpea and aimed at the introduction of varieties from international institutes. A selection of these varieties have performed over prevailing conditions and give better yields. Emphasis has been given also to selecting erect types with determinate growth habit.

Since 1984 a large number of improved cowpea varieties, combining multiple disease and insect resistance as well as early maturity, have been introduced from the International Institute of Tropical Agriculture (IITA) in Nigeria and have been evaluated. A promising variety (erect habit) has been identified which matures in nearly 70 days (TVU 1502). This was accepted by and popular with the farmers.

Objectives of cowpea breeding at Central Agricultural Research Station (CARS) are as follows:

1. Correspond with international institutes in order to obtain different sets of available germplasm.
2. Testing the performance of the introduced germplasm under local agro-climatic conditions.
3. To conduct multi-location testings on promising varieties producing good establishment and having broader adaptation.
4. Implementing on-farm research with improved stocks and local

ecotypes under farmers' methods.

5. Improve cultural practices for selected materials in respect to plant growth habit (determinate and indeterminate, erect, spreading and trailing).

6. Collect local germplasm form various locations in Somalia.

7. Develop seeds with good palatability and desirable colour acceptable to the consumers.

Cowpea and mungbean follow groundnuts as the most important grain legumes in Somalia. Both crops are important to subsistence farmers who often intercrop the legumes with sorghum or maize. Somalia has a number of local land races of cowpea.

There have been national programmes during the past to develop improved varieties of cowpea. A number of these varieties are now in trials at Afgoi, CARS and some look promising. Plant type is receiving special attention with cowpeas. A bush-type plant which matures uniformly and bears pods at the top would facilitate machine harvesting. It would also make the crop more fitting to large-scale farm operations as well as suitable for intercropping with cereals like maize and sorghum. At present, local spreading varieties are not so suitable to intercrop with cereals. To get erect varieties suitable for machine harvest and good yielding varieties, outstations started to conduct agronomic trials. Some of the experiments going on at CARS for cowpea improvements are as discussed below.

Evaluation of Cowpea Varieties Introduced from IITA

The objective was to evaluate the adaptation and yield potential of nine experimental cowpea introductions from IITA while comparing their performance with the local variety.

The nine introductions from IITA are erect and determinate in growth habit. On the other hand, the local check, a black-eye seed type, is spreading and indeterminate. The trial was planted during the October-December season. The experimental design was a randomised completed block. There were four triplecations. Individual plots were 4 x 2 m, with four rows; spacing was 50 cm between the rows and 20 cm within the rows.

Triple superphosphate was applied. The plots were irrigated three times at intervals of fifteen days. There were three hand weedings. Insecticides were applied four times; there was one application of diazinon and three of monocrotophos. Each variety was harvested twice, with data of the first picking providing criteria of maturity. Grain yields were determined from harvesting the two centres of each plot.

Grain yields and the number of days from planting to the first harvest are presented in Table 2. Grain yields ranged from 108 to 1343 kg/ha. Three introductions showed outstanding promise with yields of more than 1200 kg/ha. The lowest yield was from the local check. Under the conditions of this experiment the new introduction displayed yield potential superior to that of the local check.

Table 2. Grain Yields and Relative Maturity of Ten Cowpea Varieties.

Entry No	Variety	Grain yield (kg/ha)	Days to maturity	% Yield in 1st harvest
1	TVX 7-5 H	525	61	41
2	TVX 309-IG	1343	80	91
3	TVX 1193-7D	573	72	80
4	TVX 1193-012H	660	83	73
5	TVX 1576-OIE	1218	72	70
6	TVX 1576-OIE	820	88	80
7	ER - I	905	71	85
8	ER - 7	1205	71	79
9	4R-0267-IF	1025	72	80
10	Local check (Black eye)	108	69	47

35647

Profile of the Bean Research Programme of Rwanda

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Introduction

Rwanda is a small country with increasing demographic pressure. Recent surveys report 280 inhabitants/km2 of arable land. The country is hilly with altitudes ranging from 1000 to over 4000 m. Rainfall measures 800 mm in the east and 2000 mm in the west. Temperatures range from 15°C in the high altitudes (>1800 m), 19°C in the medium altitudes (1500-1800 m) and 21°C in the low altitudes (<1500 m).

The population pressure is forcing the country to increase efforts to support agriculture in general and bean production in particular since beans are a major component of the Rwandan diet. ISAR is defining its research programmes according to the needs expressed in the national guidelines for agricultural development. Bean research at ISAR is mainly carried out at three stations: Rubona (1650 m), Karama (1400 m) and Rwerere (2060 m).

Since 1984 ISAR has been collaborating with CIAT's regional bean programme for the great lakes area which is hosted by ISAR at Rubona. Until now, the research has been focused on breeding, agronomy, pathology, on-farm trials, biological nitrogen fixation, socio-economic surveys and the cooking qualities of beans.

Objectives

Each of the above mentioned research disciplines has its own specific objectives. These are discussed below.

Research focused on varietal development has had the following objectives:

- genetic improvement of local varieties through crossing with disease resistant, high yielding varieties.
- selection for high and stable yields.
- selection for tolerance or resistance to the predominant diseases in the country which are ascochyta, angular leaf spot, anthracnose, bean common mosaic.
- selection of seed qualities (colour and size) acceptable to both farmers and consumers.

- selection of varieties which are tolerant to climatic stress (drought in the east, cold temperatures in the high altitude areas).
- selection of varieties tolerant to marginal soils (acidity, low fertility).
- selection of varieties appropriate to banana/bean association
- selection of varieties appropriate to intercropping with maize, sorghum and sweet potatoes.
- selection of varieties resistant to insect pests (bean fly, aphids etc.).

The studies on cultural methods in Rwanda have the following objectives:

- the association of beans with other crops.
- to determine the appropriate density and spacing under various systems of planting.
- to address the problem of finding staking materials for climbing beans.
- fertilization of beans.
- planting dates of beans.
- biological N-fixation by beans.

On-farm trials and survey work focus on the following issues:

- adaptation of varieties and cultural practices developed at ISAR on farmers' fields.
- study of yield limiting agronomic factors.
- knowledge of traditional bean production practices (cultural methods, varietal mixtures, sources and type of seeds).
- inventory of diseases present on farmers' fields.
- knowledge of traditional methods used for diseases and pest control.
- knowledge of consumer habits and the nutritional value of beans.

Methodology

Breeding needs a wide genetic basis which can only be found in a large collection of varieties. Therefore, collection is the first step of breeding, including maintenance and evaluation of the germplasm. ISAR has germplasm accessions from local collection and from introduction. The introduced or collected materials are first evaluated in one or two ISAR stations for general adaptation to climate and soils and for disease resistance.

The scheme followed in the varietal selection process has been shown in Figure 1. After the first evaluation, the selected varieties pass on to selection trials at different ISAR stations and are evaluated for the criteria listed in Figure 1.

For breeding purposes, mainly the pedigree method is used, after the simple crossing and with three-way individual selection in F2, F4 and the yield evaluation in F3 and F5. After that the new lines are coded and go into the selection with the other varieties.

Since 1984, we have also been receiving F2 and F3 populations from Rwanda and varieties chosen elsewhere for their resistance, adaptation to marginal conditions or yield potential. The F4 families are planted at one or several ISAR stations according to their adaptation. These families are then subjected to a bulk selection or individual plant selection. After they have been evaluated for yield, the lines are equally coded and go into the selection trial at several ISAR stations.

The best varieties from the selection trial go to the comparative trial on stations; from there, the most promising materials are planted in multilocational trials in different agro ecological zones of Rwanda. From there, the best adapted varieties in the zone go in on-farm trials (one repetition per farm). For the on-farm trials, the farmer carries out most of the operations under the supervision of an ISAR researcher.

The varieties which are judged acceptable by farmers during the on-farm testing stage are multiplied and given to the seed production unit and to different rural development projects for further testing before releasing on a large scale.

Research Results

As the ISAR annual report for 1986 is not yet published, we will only present data collected in 1985.

Breeding

Bush beans and semi-climbing beans are evaluated together. Climbing beans have separate nurseries. In general, we can find in all nurseries materials which perform better than the control. A total of 280 accessions were entered into selection trials of which fourteen were selected for comparative variety trial at Rubona in 1986 A.

Varietal Selection

Varietal selection of beans selects introduced and local materials as well as crosses which show desirable characters. Given that the varietal selection scheme is a long process, we cannot present results for each step. Instead, we only mention varieties which performed better than the check at the level of multilocational trials.

Bush and semi-climbing beans were tested at all altitudes. In the low altitudes, the variety Ikyinyange (A 197) with yield 1836 kg/ha over eleven sites was by far the highest yielder. This was true in both seasons. Second was an ISAR mixture (1699 kg) followed by Rubona 5 (1648 kg/ha) and Kilyumukwe (1626 kg/ha). The three best varieties produced 36, 22 and 21.5% more than the local mixture as control.

In the high altitude in the north of the country, the bush varieties Rubona 5 (1669 kg/ha) and Ikinimba (1787 kg/ha) out yielded the local mixture which produced 1511 kg/ha. At Gisovu, on the Zaire/Nile Divide the variety Kirundo was most productive under the acid soil condition; it yielded 209% more as compared to the local control variety. In the regional trials comprising entries from Rwanda, Burundi and Zaire, Ikinimba (1289 kg/ha) and Rubona 5 (1147 kg/ha) from Rwanda, Kirundo (1224 kg/ha) and Urubonobono (1206 kg/ha) of Burundi, and Nain de Kyondo (1145 kg/ha) from Zaire were the most promising materials.

Among climbing beans for medium and high altitudes, varieties G 2333 (2,197 kg/ha), G 811 (2,130 kg/ha), G 858 (2,226 kg/ha) were among the entries out-yielding the control variety Cajamarca.

Phytopathology Trials

A study was done to determine the factors limiting bean production, and studies were done to control disease and insect pests of beans.

Trials on factors limiting bean yield were installed on and off station to obtain information on the impact of pests and diseases on bean yields under high and low soil fertility.

Results from two seasons show that the control of diseases with fungicide gave the highest yield increases especially on the Plateau Central, the Dorsal granitique and in the Buberuka highlands. The control of insects especially of bean fly (*Ophiomyia spp*) was effective in the Bugesera zone and the highlands of the Zaire-Nile Divide.

Fertilising with manure (30 T/ha) resulted in yield increases at five locations of the Plateau Central and the Zaire-Nile Divide, but these increases were not statistically significant. It is likely that the effect of fertiliser in the trials using "Plus one" designs did not show up due to interactions with disease. Additions of lime in acid soil has increased bean yields in four out of six locations. However, only on the Zaire-Nile Divide was a significant yield increase of 80% obtained.

The study on bean disease and pest control was divided into three sections: Resistance breeding, cultural methods and evaluation of selected chemical control methods. Within these three sections, the evaluation on resistance of plant materials was the most important activity in 1985.

Since 1984, two disease evaluation nurseries have been established. A regional disease evaluation nursery (PRER) has also been formed with entries of resistant materials from Rwanda, Burundi and Zaire. Table 1 shows the best sources of resistance in PRER at Rubona, Rwerere, Mulungu and Mulongwe.

Several trials on this subject were carried out at ISAR Stations and the following observations were made:

Trials on Cultural Practices

1. Trials on spacing and densities of planting at Rwerere, Rubona and Karama suggest that a spacing of 40cm between lines and 20 cm within lines with two seeds per pocket was the best method for climbing beans. For bush beans, 30 cm x 20 cm with two seeds per hill was the best treatment.

2. Using traditional planting techniques, 30,000-40,000 stakes/ha are enough to give satisfactory yields of climbing beans.

3. Given the decreasing soil fertility in Rwanda, cow manure is a good fertiliser for beans. The application of 20 T/ha increased yield by 35% for bush beans and 43% for climbing compared to the unfertilized control in Rubona and Rwerere.

4. For the zone around Rwerere, the best planting time for beans is in the second half of September for climbing beans and in the first half of October for bush beans in the first cropping season. In the second cropping season, the first half of April gives the best results.

5. Concerning staking, yields of climbing beans supported with stakes of different lengths increased proportional to stake height up to 2 m. After 2 m the yield increase is not economically interesting.

6. Association trials of beans with other crops showed a higher return from intercropping then from monocropping.

Table 1. Some Disease-Resistant Materials in the Great Lakes Region.

Ascochyta	Collet-otrichum	Mycovellos	Phasoisa-riopsis	Pseud-omonas	Xanthom-onas	BCMV
A 185	A 240	A 212	A 3311	G 761	BAT 1220	V 8354
BAT 795	A 252	A 281	A 222	G 89	G 790	ACV 8334
BAT 1225	A 336	A 222	A 345	G 790	Red koto	ACV 8347
BAT 477	A 345	BAT 1426	A 152	G 3710		BAN 6
BAT 1297	A 149	BAT 160	A 339	G 5477		ZAV 83012
V 8354	A 182	BAT 1628	A 163	G 6384		XAN 156
PVA 61406	A 262	BAT 1275	A 246	G 6416		ZAN 83057
PVA 1406	A 116	BAT 1375	A 240			ZAN 83059
ACV 8334	A 411	BAT 1297	BAT 76	G 11254		PVA 1408
VRA 81018	BAT 431	G 3439	BAT 1510	G 14016		BAN 9
VRA 81022	BAT 76	V 8336	BAT 431	G 14645		CC 7556-22-2cm
Caraota 260	BAT 1225	PVA 1111	G 6071	V 7945		(20-4) F7
A 345	G 5971	EMP 86	G 5971	BAT 590		G 3359
A 182	G 4129	ANP 6	G 4129	BAT 1220		BAT 1297
A 116	G 5173	Equador 229	G 5173	EMP 70		PVA 1184
G 5971	G 6074	XAN 90	G 6074			PVA 1216
G 35182	G 35182	XAN 156	G 7119			PVA 5181
ZAN 83057	G 8519	ENT 141	V 7920			PVA 668
ZAN 83091	ZAV 83009	PAN 10	ACV 8334			PVA 1428
BAN 6	ZAV 83012	G 6719	Caraotas 260			VCB 81012
	ZAV 83041		XAN 58			VA 83/84122511
	ZAV 83059		BAN 6			PVA 2289
	ZAV 83058					BAT 1373
	ZAV 83091					BAT 1387
	V 8354					
	W 8010					
	V 7920					
	V 9040					
	PVA 1145					
	ACV 834					
	ACV 837					
	VRA 81018					
	VRA 81009					
	VCA 81012					

Considering the area occupied by each plant, a significant improvement was noted when bean was grown in association with sweet potatoes and maize, instead of growing in pure culture or in binary combination with each of them.

Follow-up of Improved Varieties on Farm

Results of these studies suggest that yield alone does not give a good indication of the acceptability of a new variety. In the Plateau Central for example, the highest yielding variety, Ikinimba, was the least accepted; the best appreciated variety (Kilyumukwe) was only fourth in production.

Even when farmers recognise the high yield and stability of Ikinimba, they don't like the prostrate growth habit which makes weeding difficult. The fact that the pods are hard to open at threshing and some other culinary characteristics make it still less satisfactory.

The follow-up studies will also try to find out what farmers did with a new variety a few seasons after a variety trial. This provides even better information on the acceptance of the varieties under farmer conditions.

Conclusions

The objectives of the programme are not yet fully achieved. At the same time, the results obtained are encouraging and promising. Some times technologies lose their performance when they are released at farmer level. This is the case for the varieties Ikinyange and Rubona 5 which are currently attacked by anthracnose.

The programme wishes to increase pressure on selection, regenerate these varieties through crossing with resistant stocks (lines) and accept a challenge of promoting climbing beans in areas where dwarf beans are generally grown.

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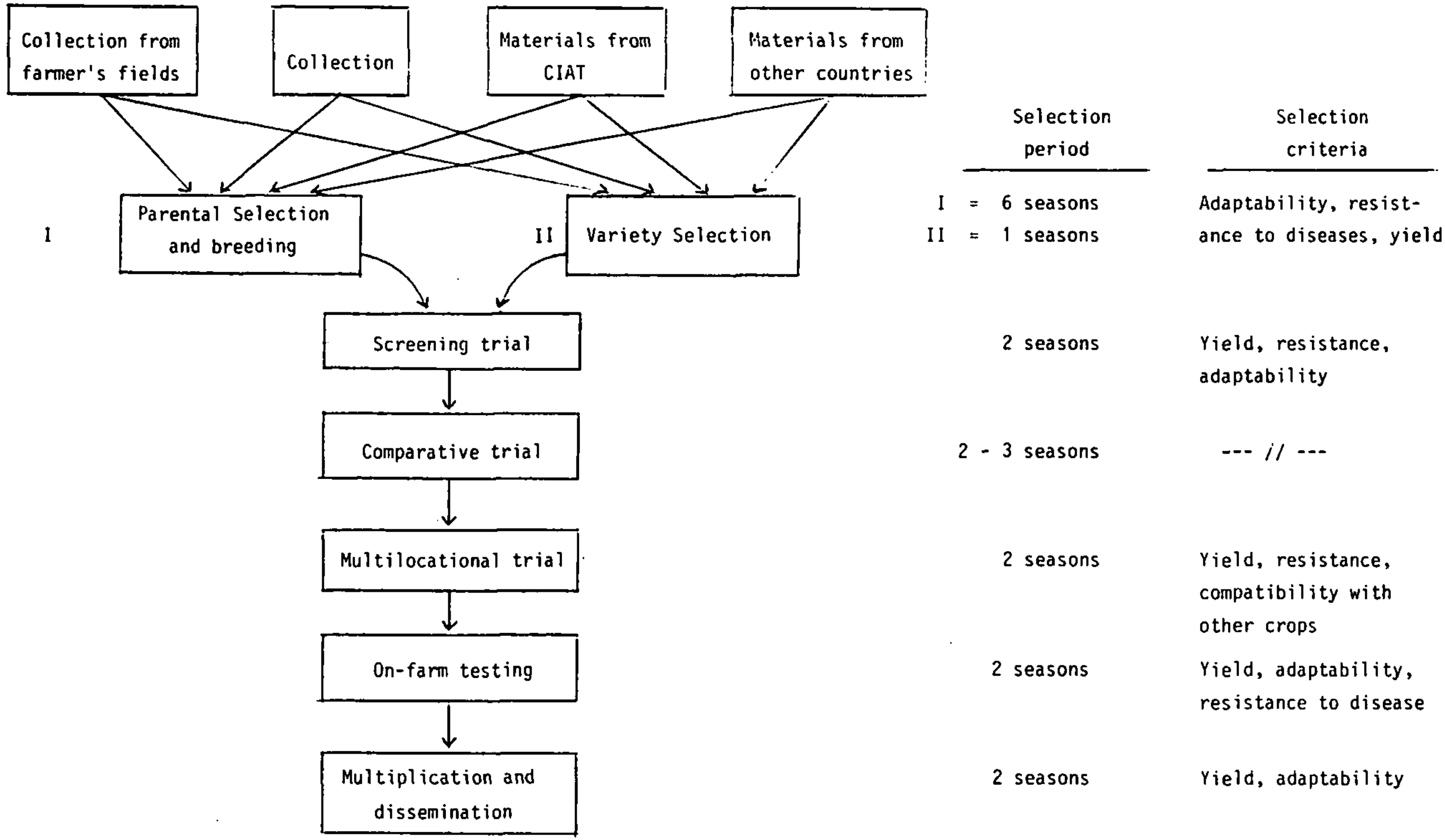

Figure 1. ISAR bean breeding and selection procedure

SUMMARY OF DISCUSSION

The region served by the Eastern Africa Regional Bean Programme includes a very wide range of agroclimatic conditions (e.g. from moist highland areas above 2,000 m altitude to hot, dry coastal areas). Importance of the crop in present farming systems also varies considerably within the region.

Research on the bean crop has everywhere a more recent origin than that on staple cereals. Among national bean programmes, that of Uganda is the oldest. Most programmes are now relatively well staffed in numbers, and the primary need is for their development through increased opportunities for training at all levels.

Bean varieties have been recommended to farmers as a result of research work conducted by the programmes of Ethiopia, Kenya and Uganda. Farmers' adoption of new varieties appears generally to have been better than for agronomic recommendations, which may have been less appropriate to the needs and resources of small farmers. Variety development programmes may have been more conscious than agronomy programmes of the need to identify products specific to the different needs of different types of farmers and markets. More recently, the wider use of on-farm research for surveying farmers' needs and testing potential new recommendations is helping to focus the research programmes of many local research stations.

The question of whether or not new varieties should be tested on-farms before their release is answered differently in the various countries of the region. The search for ways of minimising the development time for a new variety was discussed; this includes the testing of released materials from neighbouring countries, accelerated advance of extremely promising germplasm, and on-farm testing simultaneously with the last stage of on-station (multilocational) trials.

Most programmes believe that they will need to start paying more attention to bean storage and utilising research.

SESSION II: ASSESSMENT OF BEAN PRODUCTION SYSTEMS

The Contribution of Socio-Economics to Agricultural Research: A Review

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Socio-economic studies can contribute significantly to the efficiency of agricultural research (Scobie, Valdes and Dillon, 1979; Ryan, 1984). The two principal contributions that economists, rural sociologists, or anthropologists can make to the generation of improved technology are in the establishment of research priorities and in the evaluation of new technologies (Arndt, Dalrymple and Ruttan, 1977; Hardaker, Anderson and Dillon, 1984).

There are always more problems that might be researched than there are resources to achieve results. Consequently research managers must make difficult decisions to determine where efforts will be concentrated, and what will be given less, or no attention. Socio-economic investigation can provide information and analysis that can be combined with biological information to establish priorities in agricultural research.

Once agricultural research is underway, many potentially useful new technologies, like varieties or agronomic practices, are developed by scientists. Careful evaluation of these many new alternatives is essential to identify the few that will actually be useful to farmers. While a necessary part of this evaluation is biological, for example yield or disease resistance, perhaps the most stringent evaluation is socio-economic (Pachico and Ashby, 1983). Farmers are the ultimate judges of new technology. Farmer judgements of new technologies are based on their socio-economic decision criteria, for example, costs, availability of labour, cooking quality, price, production risk. Socio-economic studies make a vital contribution to the understanding and application of these criteria to the evaluation of new technologies in order to identify what is the best technology that can be offered to farmers (Rhodes and Booth, 1982).

This paper will attempt a brief general overview of how socio-economic research can contribute to progress in agricultural research.

Definition of Priorities: The Micro-Perspective

Since the fundamental objective of agricultural research is to generate new technology that farmers will use, the definition of research priorities must be based on an understanding of farmer problems, resources and objectives. The purpose of new technology is to solve farmers' current problems, but it must provide solutions that are within the reach of farmer resources and respond to the objectives of farmers.

Socio-economic field studies put researchers in direct contact with farmers, and through a variety of survey or interview techniques find out what problems farmers face (Horton, 1984; Rhodes, 1982; Byerlee and Collinson, 1980). Farmers confront agrobiological problems like diseases, insects or poor soil fertility. Farmers also confront socio-economic problems like inability to make timely land preparation, low returns to expenditures on agrochemicals or food shortages at the end of the dry season.

Through interviews with farmers, socio-economists can very quickly find out a great deal about both the agrobiological and socio-economic problems that farmers face. However, farmers' understanding of problems is often limited, for example by lack of knowledge of whether the bean crop suffers from rust (*Uromyces appendicutus*) or anthracnose (*Colletotrichum lindemuthianum*). Consequently, agronomists, pathologists and other agricultural scientists must work closely with socio-economists to understand and identify which are the most important problems that farmers face, and this may require both interviews with farmers and also scientific experiments conducted on farmers' fields as well as on the experiment station (Woolley and Pachico, 1987). The important issue here is to identify the problems that most affect farmers and give high priority to research on the major problems, and low priority to problems that howsoever interesting scientifically, are not important to farmers.

In addition to identifying problems, it is also essential to know the resources that farmers work with. This includes agrobiological factors like soil types, rainfall patterns and characteristics of farmer land races, and it also clearly includes socio-economic resources like labour, capital, draft power and knowledge. Understanding farmer resources can provide crucial insights in setting priorities. If, for example, farmers do not have the money to purchase chemical fertilisers, research on chemical fertilisers probably deserves low priority.

Understanding farmer objectives is also critical in setting priorities. Whether farmers are most interested in high yield, or achieving assured yields through disease resistance, or having erect plant types for ease of harvest, all affect how research priorities should be set between breeding objectives on yield potential, disease resistance or architecture. Similarly, socio-economic objectives of farmers like maximizing returns to land, or overcoming a labour constraint, or obtaining high returns to capital, will affect research priorities between alternatives like improved weed control, use of chemical fertiliser or selection of new varieties.

Methods of Setting Priorities

Diagnosis of farmer problems, resources and objectives requires direct interaction with farmers to find out from them about these issues. While it is important to start with a revision of existing secondary information, much of which can be useful (*e.g.* soils maps, climate data, agricultural census), often it will not be sufficiently focused or up to date to obviate the need for primary data collection by socio-economists, who in general are likely to be of low productivity unless they are encouraged and supported to do primary data collection in the field with the farmer (Gilbert, Norman and Finch, 1980).

Field work normally begins with a rapid appraisal or preliminary reconnaissance (Chambers, 1981). This rapid appraisal is most effective when socio-economists work directly in the field with agricultural specialists in agronomy, pathology etc. (Hildebrand, 1981). In this fashion both the agrobiological and socio-economic aspects of farmer problems, resources and objectives can be addressed. The purpose of the rapid appraisal is to give the researchers (not their assistants) a direct personal first-hand exposure to the real world of the farmers. Typically this activity is carried out through informal interviews with farmers over a wide range of topics (Rhodes, 1982; Collinson, 1980).

In a fairly homogenous region a few days of field work provides a basis for generating preliminary ideas or hypotheses about the most important farm activities and major problems. From this information it is then possible to plan a more structured systematic survey to test the validity of hypothesised views of farmer problems, resources and objectives (Horton, 1982; Byerlee, Harrington and Winkelman, 1982). Typically the formal survey does not require sophisticated computerised analysis, and it can usually be processed by hand within a couple of weeks to give tables of means and frequencies. On-farm trials can also be undertaken to further refine problem diagnosis (Woolley and Pachico, 1987).

It is important to recognise that in addition to socio-economic information gathered through interviews, the diagnostic rapid appraisal and survey should also include the taking of agronomic data in the farmers' fields. Incidence and intensity of disease and pest attack should, for example, be observed directly in the field. This essential part of the definition of farmer problems clearly requires the collaboration of biological scientists in the diagnosis. Moreover, often neither the agrobiological nor the socio-economic problems (eg. measurement of labour flows) can be assessed with sufficient accuracy in a single visit. This may require that the diagnosis be seen not just as a quick rapid appraisal or a single visit survey, but as an ongoing iterative process of contact and dialogue with the farmer, through which researchers' understanding of farmer circumstances is deeply enriched. Such a process can also lead to quantitative estimates in a multiple regression framework of yield limiting factors (Pinstrup-Anderson *et al.*, 1976).

This process of revision of secondary data, rapid appraisal, survey and exploratory trials can very quickly at low cost generate baseline data to set agricultural research priorities. For example, studies in Rwanda found that bean farmers select different varieties for low fertility soils and high fertility soils, as well as for whether they are planting in monoculture or in association with bananas (Voss, 1987). Consequently screening for improved bean varieties must take soil status and cropping systems into account.

Definition of Priorities: The Macro Perspective

While socio-economic research conducted in collaboration with biological research can generate much information on former problems, resources and objectives that can be used to help set research priorities, research directors responsible for deciding priorities must also take into account broader scientific, socio-economic and political factors. Tractability of a scientific research problem and expected magnitude of progress is a major factor in setting priorities. For example, ease of obtaining a disease resistant variety and the contribution to yield of improved resistance must be considered in setting priorities.

Socio-economic analysis can contribute to the assessment of the potential impact of a new technology: projecting how many farmers would be able to adapt a new technology; assessing whether the technology would benefit all farmers, or for example, only those who have tractors; estimating the amount and value of additional production that could result from a new technology. Clearly, there is a major input that economists can make to research directors in appraising the potential benefits and their distribution from new technologies (Pachico, Lynam and Jones).

Finally, the research director sets priorities in light of the nation's political objectives (for example, increasing production, exports, helping the poor, or improving nutrition) and taking into account the technical considerations of what is possible and the economic analysis of what the impact would likely be.

Economic input to priority determination can sometimes usefully extend as far as formal cost/benefit analysis (Pachico, Janssen, Lynam and Jones, 1983), but the data needs for such a formal approach sometimes can be quite high, and experience even in situations with ready access to advanced computing facilities suggests that artful judgement is usually required for final decision making, and that formal analysis is best viewed as indicative or illustrative rather than mechanically deterministic (Ryan, 1984).

Socio-Economic Evaluation of New Technology

After priorities have been established, agricultural scientists can begin to rapidly generate improved technologies, be they new varieties or novel agronomic practices. Naturally, these new technologies must be tested in scientific experiments, and there is a growing consensus that many of these experiments can best be conducted in farmers' fields (Norman, 1980; Byerlee and Collinson, 1980). The evaluation of technologies tested in these trials passes through phases, the first of which is agronomic. That is, the first analysis is a statistical analysis of the difference between treatments in a trial (Sanders and Lynam, 1982).

A large number of different varieties or cultural practices can be tested in on-farm trials, and these can easily be subjected to economic analysis through comparative budgeting. The data requirements for this analysis are minimal, consisting of the results of the on-farm trials and data on the costs of the treatments in the trial. Careful thought is essential, but computational requirements are also modest, making it feasible to quickly analyse a large number of treatments and trials.

The methods for conducting comparative budgeting are well documented and straightforward (IRRI, 1984; Perrin *et al.*, 1976). Budgeting permits analysis of overall profitability and of returns to land, labour or capital. It can be easily adapted to examine market-oriented or subsistence production, or to contrast decision-making between owner-operators and renters. Some assessment of risk is also possible. Thus, budgeting is a very supple tool, of low cost to use and only limited in use principally by the skills and capacity of the economist.

Budgets are also the building blocks of whole farm programming models that can assess a new technology in the whole farm, not just in comparison to the current technology of a single crop. Programming models have the additional advantages of estimating shadow prices or the marginal productivity of factors which give a good guide to estimating minimally acceptable returns, and they also can simulate change in cropping patterns or undertake sophisticated analysis of risk. However, the analytical and computational requirements of programming models are so high that there is a strong sentiment among leading economists that frequently they are more trouble than they are worth (Anderson and Hardaker, 1979). Moreover, the quality of both budget analysis and programing models depends critically on the economist having a very clear accurate understanding of farmer objectives and resources. These economic analyses can be very misleading if the economist has an erroneous perception of farmer objectives and resources.

Of course, the farmer is the one who best knows what the farmer's objectives are. Consequently, probably the best evaluations of new technology are obtained directly from the farmer (Ashby, 1986). Interviewing the farmer in detail about what the farmer perceives as the major advantages and disadvantages of the technologies tested on-farm can be the most useful form of evaluation of technology. For example, trials of new bean varieties in Guatemala showed conclusively that farmers saw as a major drawback the fact that the improved varieties were ten days later than traditional varieties. The importance of this problem would not have come to the attention of breeders, agonomists or economists, without having had a direct evaluation of the new varieties by the farmer (Pachico).

Similarly, in Rwanda the highest yielding bean variety in on-farm trials, Ikinimba, was not acceptable to farmers due to several factors: its sprawling plant type that made weeding difficult; it was difficult to thresh; and had a less preferred grain colour (Voss 1987). Other examples of economic analysis of new technical alternatives have looked at the possibility of alley cropping in Nigeria (Ngambeki, 1985) and introduction of draft power for land preparation in Zambia (Rukandema, 1986).

Besides having farmers comment upon desirable and undesirable characteristics observed in on-farm trials, follow up interviews with farmers in cropping seasons after on-farm trials are an especially effective form of evaluation. The method is quite simple. A list is maintained of farmers who have participated in trials, received an extension demonstration or purchased the seed of a new variety. They are left for a year to manage their crop by their own judgement, without further influence from researchers or extension officers.

Then, a year later the farmers are interviewed to find out whether they have continued or not with the new technology, and why. In many respects this is truly the acid test of a new technology. If a high proportion of farmers continue to use the new technology, researchers can be quite confident that it is indeed suitable, and an intensive extension effort is justified. If, however, many farmers are not using the technology, almost regardless of what they say about whether or not it is good, researchers should be warned that there is likely to be a significant problem with the new technology.

Once new technologies have been recommended and extended to farmers, adoption surveys can provide very useful feedback on diffusion by interviewing a random sample of farmers from within the relevant target area. This permits measurement of the proportion of farmers who are aware of the new technology and have had access to it. Roughly this information assesses the breadth of extension coverage and availability of the inputs needed for the new technology (*e.g.* seeds). The adoption survey also measures how many farmers are using the new technology, on what proportion of their area and with what result. Particularly important is to obtain farmer evaluation of the advantages and disadvantages of the new technology. Care should be taken to see if any farmers have used the new technology in the past, but have now stopped using it, and why. Thus, adoption studies serve two purposes: measuring the impact of new technology and identifying constraints to adoption (Hardaker *et al.*, 1984; Horton, 1986).

Estimation of the impact of new technology provides a crucial documentation to demonstrate the value of investment in agricultural research to political decision-makers. The constraints identification generates essential feedback about shortcomings of current technology that can serve to orient ongoing or future research. Constraints identification can also point to areas where institutional services can be improved (*e.g.* seed production, extension) to accelerate the diffusion of new technology.

Thus, socio-economists can make an effective contribution to the evaluation of new technologies. Economic budgeting analysis, farmer evaluations, follow-up surveys and adoption studies are useful techniques for evaluation to tap farmers' views of how the new technologies meet their objectives, match their resources and solve their problems.

Conclusions

Socio-economists can provide important information and insights both to the setting of agricultural research priorities as well as to the evaluation of promising new technologies. Rapid appraisals, exploratory surveys and other field data gathering exercises can be very useful in understanding farmer problems, resources and objectives to establish micro-level research priorities, while some economic analysis is essential to any macro-level assessment of priorities. Socio-economics is also a critical part of technology evaluation through economic budgeting analysis, farmer evaluations, follow-up surveys and adoption studies.

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A Diagnostic Survey of Kabale District, Uganda

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Introduction

Presently, there is an increasing policy concern for meeting the needs of small scale farmers, many of whom are isolated from the research process. Research must be of increasing relevance to both the farmers' physical environment and the socio-economic setting of their farm activities. Natural resources and economic conditions of research stations are different from those in which small farms operate. Farmers' needs and circumstances are always specific to local situations. Therefore, there is a need to carry out on-farm research which focuses on the farmers' real problems and obtains results under the farmers' normal (actual) conditions of production, with the participation of the farmer. Farmers possess a great amount of knowledge about their environment and enterprises and have different ways of solving their problems. It is important that the farmers' knowledge as well as that of modern science be brought together to bear on any given problem.

Methods

Background information about the area was collected from the Kabale District Agricultural Office (DAO) and extension workers. Four representative villages were randomly selected for a diagnostic survey. Two extensionists were chosen to join the survey and to inform the local leaders and farmers of the purpose of the visit. The interviewers (three agronomists, a soil scientist, a pathologist, a breeder, a biometrician and two extensionists) were given a one-day training in Farming Systems Research at Kachwekano District Farm Institute. The survey was carried out with the help of a questionnaire; 27 farmers were interviewed. It took four days to complete the survey. The team dicussed its findings at the end of each day.

General Description

In Kabale district the area surveyed includes the following sub-locations: Hamurwa, Rwamucucu, Naziba and Kabanyonyi. The area is montane with an altitude of 1800-1950m above sea level. The mean monthly maximum temperature ranges between 22.2° - 23.9 °C. Beans stay long in the field in Kabale because of the effect of low temperatures. It is estimated that beans stay in the field for 87, 95, 96 and 109 days in the northern, central, eastern and western regions respectively (Mukasa, 1970). The days to maturity depend on many factors, but most of the bean cultivars grown in Uganda generally take 70 to 90 days to mature.

The area experiences two rainy seasons extending from February to May and August to December. This allows a continuous supply of beans all the year round. The soils are mainly reddish brown, sandy loams and volcanic soils with medium to high fertility depending on use. Soil erosion is evident on many farms. In many cases terraces have been cultivated or destroyed because farmers do not have enough land; after many years of rest the terraces were found to be more fertile (productive) than the other pieces of land which are cultivated continuously with either short or no fallow period. The average farm size is rather difficult to estimate because all the land is fragmented. Estimates of the farms visited range from 1 to 22 ha. Due to land fragmentation farmers waste a lot of time and energy moving from one piece of land to another. Some farmers have to walk as far as 4km from home to their fields. A number of farmers indicated that the advantages of land fragmentation are: (a) each farmer may have both fertile and poor land which might not be the case if land were consolidated, (b) each farmer may have pieces of land on the hilltops, valley bottoms or on steep slopes, (c) it reduces crop loss due to diseases, pests, hailstones and land slides. Since all the fields of a particular farmer are not in the same area, it is likely that some fields will not be affected.

All the farmers visited operate their own land which they inherited from their parents or bought. This implies that many farmers would have no fear of investing in the land (by fertiliser application and soil and water conservation) because they own it. A few farmers rent land in addition to their own. The dues paid are negotiable depending on the amount of land and its productivity.

As regards communication in the area, Kabale town is accessible, but the feeder roads are in poor condition especially during the wet seasons, for example, Kisoro road and Rukungiri road. The poor roads make means of transport scarce and very expensive, hence marketing is a problem.

Farming Systems

Of the farmers visited, 75% grow sorghum as their priority crop. Other important crops include beans, bananas, sweet and Irish potatoes, peas, tobacco, maize, vegetables, coffee and millet. A few animals are kept in most homes. These are cattle, goats, sheep, pigs, chicken and ducks.

Mixed cropping is a common practice in the area. Beans are intercropped with maize, sorghum, Irish potatoes, peas, pumpkins, sweet potatoes or bananas. Intercrops are more common than pure stands of beans. Bush types of beans are preferred for intercropping because they do not twine round the associate crop. Irish potatoes are planted on ridges and the beans are planted in the inter-ridge spaces. When interplanted with sweet potatoes, both the beans and the potatoes are planted on top of mounds. Where beans are interplanted with maize, sorghum, pumpkins or bananas, they are sown as cover crops.

Relay intercropping is also widely practised. Maize and beans are planted in the same field at the same time. When the beans reach maturity they are harvested and sorghum is sown in that same field so that it becomes a sorghum/maize intercrop. Sometimes the sorghum is sown a few weeks before the beans are harvested.

Many farmers stagger the planting of beans because they want to avoid the heavy rains and diseases which reduce yields. Some beans are planted at the onset of the rains while others are planted after the rains have decreased. Staggered planting may also be due to labour shortage. Farmers plant sorghum first, and the other crops are planted later. Where beans are intercropped with sorghum, they have a chance of being planted early in the wet season. They are also weeded early because farmers weed sorghum first.

The farmers visited gave the following as their main reasons for interplanting: (a) to obtain a variety of food crops from the same field (because land is scarce); (b) to reduce risk in case one crop fails; (c) to smother weeds by providing an adequate ground cover and (d) to ensure that the little labour available is shared by a number of crops.

Agricultural Technology

Land Preparation

Land preparation starts toward the end of the dry season and it is done by hoe. The steep slopes in the area make it almost impossible to use tractors for land preparation. Most of the farmers dig twice and remove the trash before planting. About 20% of the farmers heap the trash in a ridge which runs across the field to prevent soil erosion. Some farmers also dig trenches around their fields so that the run-off does not flood the fields and carry the top soil away.

Planting

The major planting seasons for beans are from February to May and August to September. The farmer carries a small hoe in one hand, cuts the soil, drops one or two seeds per hole using the second hand and covers the seed by kicking the soil as he moves forward to make the next hole. This is called the chop-and-plant method. The beans are not planted in lines and the spacing varies from farmer to farmer. A few farmers plant beans by standing at one end of the field and throwing handfuls of seeds on top of the soil. The seeds are then covered with soil. This method is faster than the chop-and-plant method but the seeds cannot be covered adequately and it is difficult to regulate the spacing or plant density.

Varieties

The most common varieties in their order of preference by the farmers are: Rushare, K20, Kikoona, Bwanalesi, Bweseri, Gabangonyi and Mwenda. Rushare is liked for its taste, quick maturity, high yield and dark red colour which makes thick soup. It also fetches a high price on the market. K20 is mainly liked for its colour and tolerance to pests and diseases. Kikoona is high yielding and takes a short time to cook. Bweseri is well known for its tolerance to pests and diseases. Bwanalesi is an early maturing variety.

Table 1. Preferred Characteristics of Bean Cultivars, Indicated by Percentage of Farmers.

Characteristics	CULTIVARS				
	Rushare	K20	Kikoona	Bweseri	Bwanalesi
Taste	80	27	25	-	-
Quick maturity	43	36	12	17	75
Cooking time	33	27	50	-	25
Yield	66	36	50	-	-
Colour	52	54	-	-	25
Tolerance to pests and diseases	33	45	38	66	25

Table 1 shows the percentage of farmers who named a certain cultivar as being the best with respect to the given characteristics. Generally, farmers in this area do not like varieties which have an indeterminate prostrate growth habit (type III). This is because the farmer cannot move freely through the field when weeding or spraying the crop with chemicals. On the other hand, prostrate varieties cover the ground and smother weeds at an early stage compared to bushy types. The farmers may need to increase the density of plants per hectare using the bush types in order to suppress weeds.

Most farmers grow land races, and most of them are very susceptible to pests and diseases, resulting in low yields. The breeders in the National Bean Programme have already made arrangements to incorporate resistant genes into some of the farmers' favorite land races. Some varieties which are adapted to the area will be selected from Kachwekano sub-station which caters for Kabale district. The selected varieties will be those which bear the characteristics desired by various farmers. A few seeds will be given to farmers to plant in their fields and to evaluate their performance and taste.

Fertiliser Application

None of the farmers visited apply industrial fertilisers to land because they are unknown, unavailable or very expensive. In Maziba, 80% of the farmers apply manure to their fields though they do not apply it directly to the bean crop. In Hamurwa, 71% of the farmers use manure and more than half of these farmers apply it to the bean crop. The same applies in Rwamucucu.

Weed Control

The common weeds in their order of abundance are: *Galinsoga parviflora* (Gallant Soldier), *Bidens pilosa* (Black Jack), *Commelina benghalensis* (Wandering Jew), *Digitaria scalarum* (Couch Grass), *Oxalis latifolia* (Oxalis), and *Tagetes minuta* (Mexican Marigold). These were given respectively as "Mpunika, Nyabarashana, Eteija, Rumbugu, Kanyoobwa" and "Nyamunuuka" in the local language. All farmers weed their beans whenever it seems necessary to do so; 40% of the farmers weed twice. Mukasa (1970) recommended that beans should be planted in a clean seed-bed and weeded once or twice before flowering. Weeding is done by hoe. Sometimes it is done late because there is not enough labour to weed in time, thus reducing yields. None of the farmers visited use herbicides because they are unknown to some of them and very expensive. Some farmers requested subsidised prices of herbicides. For 70% of the farmers the most difficult operation to complete in time is weeding sorghum; consequently all the other activities are delayed, such as planting sweet potatoes, weeding Irish potatoes and beans, and preparing land for peas. Peas are never weeded.

Diseases and Pests

Many farmers were not aware of the diseases but thought that the bean crop was spoilt by the rain. Diseases observed include: anthracnose, angular leaf spot, halo blight, common bacterial blight, bean common mosaic virus and rust. The bean weevil, *Acanthoscelides obtectus*, is common in stored beans. Aphids were reported by over 60% of the farmers. The magnitude of the damage caused by pests and various diseases is not well defined.

Farmers in Maziba and Kabanyonyi use chemicals like fenitrothion, DDT, Dithane M45, etc. Others use ash or plant their beans when the rains have decreased. Many farmers emphasised the need for chemicals and sprayers at subsidised prices.

Harvest

Harvesting starts as soon as the pods ripen (stage R9) and continues up to the time when the pods are dry. The whole plant is uprooted and dried in the sun until it is threshed and winnowed.

Marketing

Most farmers have access to a weekly market in a neighbouring village. Farm produce is sometimes bought at home by buyers from Kabale town but they usually give low prices. These private buyers transport the produce to Kabale and later on to Kampala. Prices are usually high at the beginning of the wet season but they decline at harvest time. If farmers could store their beans safely so that they can regulate the supply of beans on the market, perhaps it could help to stabilise prices and avoid low incomes during harvest time.

Socio-Economic Aspects

There are a number of primary schools in all the areas visited during the survey, but there are few secondary schools. This implies that many children leave home to attend school in other areas, thus creating a labour shortage.

Family size ranges from two to nineteen with an average of eight persons per family. Most houses are constructed with mud and wattle and corrugated iron or papyrus roofs. The walls are either white washed or painted with local reddish brown paints and decorated in black paint. Many households do not have adequate granaries for the storage of beans. Sorghum as the priority crop occupies the few granaries that are available.

Foodstuffs consumed include sorghum, beans, sweet potatoes, Irish potatoes, peas, bananas, maize, vegetables, millet, meat, milk and eggs. Beans are the major source of protein in most of the homes.

Agricultural inputs such as insecticides, fungicides, industrial fertilisers, sprayers, herbicides are so expensive that most farmers cannot buy them. The nearest market from which they can be purchased is Kabale town. These inputs are not sold in the weekly markets which are found in various villages. This makes them unavailable to the local farmers who cannot travel to Kabale town. Certified seed is also usually unavailable to the farmers who cannot travel to Kabale town.

Generally, women do most of the work on the farm. Men assist them particularly in the production of cash crops. Of the farmers interviewed, 92% hire labour at an average of four labourers each. The average payment is 3,500/=with lunch or 5,000/=per day without lunch. Almost all farmers hire labour for all activities where labour is a constraint, that is to say, land preparation, planting, weeding, harvesting, carrying produce to the market and maintenance of banana plantations.

The busy period falls between November and April with its peak occurring in December to January when most of the farmers are planting sorghum and preparing land for planting beans and peas. In February sorghum is weeded, and beans, peas and Irish potatoes are planted. It would be helpful to introduce herbicides for use on sorghum so that the farmer is relieved of the difficult task of weeding. This would release labour for other crops. Other operations which farmers find difficult to complete on time are land preparation and maintenance of banana plantations.

The slack period is between July and August when the only activity done is harvesting. To reduce the amount of work done during the busy period, some activities, such as mulching the banana plantations, should be done during the slack period (July to August).

At least 75% of the farmers are members of rural farmer organisations and indicated that they have access to credit facilities. Most of these organisations are credit and saving societies, such as Kibuzigye Bika/Oguze; Karukara Bika/Oguze; Mparo Bika/Otungye; Rwamucucu Vegetable Growers' Union; Nyanja Bika/Oguze; Kabanyonyi Tube Hamwe, etc. The farmers named fourteen rural credit and saving societies from which members can obtain credit with or without security. This implies that in cases where extra resources are required to adopt improved technology, farmers can obtain such if they wish to do so. The presence of farmers' organisations also permits fast diffusion of recommendations because many farmers are made aware of the technology at the same time.

Problems Identified

1. Lack of inputs:
   - farm implements (such as hoes)
   - fertilisers
   - insecticides, fungicides and herbicides
   - spray pumps
   - certified seed.

2. Pests and disease:
   - aphids, bean flies, beetles and cutworms
   - angular leaf spot, halo blight, anthracnose, bean common mosaic virus, etc.

3. Land deterioration due to:
   - continuous use of land
   - inadequate rest periods
   - soil erosion.

4. Land shortage due to the increasing population.

5. Natural hazards:
   - Rainfall (high intensity and associated with diseases)
   - Hailstones
   - Land slides
   - Dead swamps.

6. Low yields as a result of 1 - 3, 5 above.

7. Lack of adequate storage facilities:
   - granaries
   - protection against storage pests.

8. Low prices of farm produce:
   - lack of transport
   - poor roads.

9. Lack of cash:
   - to employ labour
   - to purchase inputs.

10. Lack of knowledge about recommended practices.

Recommendation Domains

The area surveyed was divided into two recommendation domains depending on the methods used by the farmers to solve their problems. Farmers in Hamurwa and Rwamucucu (RD I) do not use agro-chemicals while those in Kabanyonyi and Maziba (RD II) do though they find them expensive to obtain.

Table 2. Problems Faced by Farmers in each Recommendation Domain

	RD I	RD II
	% farmers	
Pests	21	40
Diseases	21	50
Lack of agro-chemicals	43	40
Land shortage	21	10
Weeds	14	10
Heavy rain	21	20
Hailstones and land slides	36	10
Soil erosion	28	-
Soil infertility	7	10
Lack of cash	7	10
Lack of seed	14	10

Research Needs

In both recommendation domains, the priority problems (where research can be done) are pests and diseases and the lack of chemicals to control them. There is a need to carry out yields loss trials to ascertain how much damage is caused by the different pests and diseases. Resistant varieties could be introduced in RD I and their performance compared to the land races. In RD II where farmers already know which chemicals to use, the existing farmer organisations should try to purchase inputs (such as chemicals) in a group so that members can get access to them or obtain credit to buy them.

Weeds are not considered a major problem in beans, but they are a problem in sorghum which is the priority crop. It would be useful to find out whether use of herbicides such as alachlor (Lasso) which can be used in an intercrop of sorghum and beans would solve the problem. The use of Laddock (benazon + atrazine) as a post-emergence herbicide in sorghum could also be investigated to find out the possibility of releasing labour from weeding sorghum to perform other activities in the farming system. Since the majority of farmers hire labour, it would be helpful to compare the cost: benefit ratios of using herbicides versus hired labour in RD II.

With regard to the problem of land deterioration, wherever experiments are laid there will be some anti-erosion bands constructed for soil conservation. There is also a need to find out the methods used by farmers in processing manure and the rates and timing of its application.

Another researchable area is the use of locally available material to construct granaries and application of ash, banana juice and sunflower oil to control storage pests.

To alleviate some of the marketing problems, the existing farmers' organisations could make arrangements to buy produce from farmers, hire transport and take the produce to town where it fetches a high price.

The information obtained during the diagnostic survey will be used to plan appropriate research to solve the major problems of target groups of farmers. Experiments will then be conducted on selected farmers' fields. This is intended to enhance the adoption of improved technology. It will also strengthen the linkage between extension and research and improve on both.

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Reference

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Figure 1. Cropping Calendar

Crop	Operation	S	O	N	D	J	F	M	A	M	J	J	A
Sorghum	Land prep.		*	*	*	*	*						
	Planting			o	o	o	o	o					
	Weeding				+	+	+	+					
	Harvesting										@	@	@
Beans	Land prep.	*			*	*	*	*	*				
	Planting	o	o			o	o	o	o	o	o		
	Weeding	+	+				+	+	+	+	+	+	
	Harvesting			@	@	@				@	@	@	@
Potato	Land prep.	*	*			*	*	*	*	*			
	Planting	o	o				o	o	o	o	o		
	Weeding		+	+	+			+	+	+	+		
	Harvesting					@	@				@	@	@

33223

Farm Survey Results and On-Farm Trials in the Nazreth Area, Ethiopia

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Introduction

A farming system survey was carried out in Nazreth area in the central zone of Ethiopia at the end of 1985 and the beginning of 1986. The survey area included parts of the rift valley which are present and potential areas for haricot bean production.

The main objectives of the survey were to describe and understand the farmers' natural and socio-economic circumstances and the farming system which farmers manage and also to identify and verify production bottle-necks in the system so as to guide future research priorities. The survey included an informal survey followed by a formal one. More than 50 and 117 farmers were interviewed by informal and formal surveys, respectively.

During the survey, information was gathered on the various aspects of the farming system. Haricot bean being one of the major crops in the region, great attention has been given to understanding the way farmers produce and manage the crop. Therefore, in this paper, some of the cultural practices used by small farmers and the associated problems limiting bean production are discussed. The results of a package testing programme in beans conducted between 1980 and 1983 and the outcomes of an on-farm variety verification trial undertaken in 1986 are also included.

Farm Survey Results

The survey identified that haricot bean plays a major role in fulfilling the cash and food requirements of small holders in the mixed farming zone of the Nazreth area. Haricot bean is used for food occasionally and consumed at home in the form of "Nifro" (boiled grain) either alone or mixed with other cereals such as maize and/or sorghum. "Nifro" is a preferred food during the wet season when the farm family including children are engaged in the various activities. Therefore, the farmer's wife can easily process beans into "Nifro" since its preparation does not compete much with the family's labour or time. Haricot bean is also used to prepare a local stew, "Shuro Wat".

The farming systems survey conducted in 1986 indicated that

52% of the farmers in the Nazreth area produce haricot bean while a study done in 1979 showed that 82% of the farmers produced haricot bean. The difference could be attributed to the more attractive price farmers of the area enjoyed in the mid-70s when haricot bean was considered to be a "White Gold."

Table 1. Crop Calendar for Major Crops

Crop	Land preparation	Planting	Weeding	Harvesting
Maize	April	April-May	July	Oct.-Nov.
Sorghum	April	April-May	July	Nov.-Dec.
Teff	June-July	July	July-Aug.	October
Haricot bean	June	July	August	October

The average area of land allocated to haricot bean per grower is about 0.44 ha; the total area owned by a farmer is about 2 ha. Haricot bean is planted during the main rainy season (June-July). When farmers fail to plant their early crops such as maize or sorghum, due to shortage of rain or time, they put more land under haricot bean production.

Seed Bed Preparation and Planting

Land preparation for haricot bean starts in early June. Survey results showed that 63% of farmers plough twice before planting. However, depending on the rainfall conditions and availability of time, the frequency of ploughing may change. Therefore, if farmers are busy they do only one ploughing or they directly sow the crop and cover the seed. The farmers do their soil cultivation with the traditional wooden "Maresha" plough. This plough has a crumbling rather than turning action and works fairly shallowly, about 10-15 cm. Method of planting is by broadcasting followed by light soil covering using the local plough. None of the farmers practise row planting because it is time consuming and farmers do not own row planters.

Farmers use a minimum of 60 kgs of seeds for a hectare; 45 kg/ha is the recommended rate. According to Tesfaye Zegeye (1982) the seed rate could reach up to 116 kgs/ha. Farmers deliberately increase the seed rate to have an early dense canopy of haricot bean seedlings which can dominate weeds. Furthermore, farmers tend to use higher seed rates where they expect poor seedling emergence.

Fertilisers

Fertilisers are used to a limited extent. Only 6% of the surveyed farmers claimed to use commercial fertiliser (diammonium phosphate) in the 1985 crop season. The average rate of fertiliser used was 60 kgs/ha. Use of animal manure as a means of maintaining soil fertility is not a common practice for haricot bean. Farmers reported that manuring could cause lodging to the crop and it also aggravates the problem of weed infestation.

Weeding

Compared to other crops, haricot bean had the least priority in weeding. About 90% of farmers reported not weeding haricot beans. The rest weeded only once, and no farmer weeded more than once. The main reason for not weeding beans as reported by 70% of the farmers was overlapping of work schedules. Farmers are busy planting and/or weeding teff, maize and sorghum when haricot bean requires weeding. (Refer to crop calendar Table 1.) They also believe that haricot bean tolerates weeds better than other crops. The weed problem is also minimised by using high seed rates. A study made in beans at Nazreth Research Center also favours the use of higher seed rates especially if the weed infestation is high and complete control of weeds cannot be achieved.

Diseases and Pests

The major disease observed in farmers' fields is common bacterial blight (*Xanthomonas campestris pv. phaseoli*). The common pest is storage weevil (*Callosobruchus* spp). Though the crop loss due to these factors and disease is economically important, so far no alleviation measures have been taken by the farmers. The Nazreth Research Centre has already established some recommendations to control the above-mentioned pest and disease.

Harvesting, Storage and Disposal

Farmers usually harvest their bean crop in October. Harvesting is done when most of the pods and seeds are dry. The plants are pulled out and left in small stacks in the field. After some time they are transported, on human or animal back, to the threshing ground. This consists of consolidated earth. Threshing is done by oxen trampling the beans; threshing by oxen is always supplemented manually. The haulms are separated with forks and the seed winnowed.

If the beans are harvested late in the day, shattering of the crop is very high. Therefore, farmers harvest the crop early in the morning before the dew has dried off.

The average grain yield per hectare is 600 kgs. Beans are usually sold immediately after harvest but seldom stored in locally made grain elevators, "gottera". However, to date, sacks are also used for the purpose of storing bean seeds.

The farmers in the Nazreth area usually plant white seeded haricot bean which has a good market price and is usually used for export purposes. However, for home consumption, they produce coloured haricot beans which are large seeded and have a good taste.

Farmers are required to sell part of their produce to the Agricultural Marketing Corporation (AMC) or Ethiopian Oil Seeds and Pulses Exporting Corporation (EOPEC) at fixed prices on a quota basis. The remainder is sold in open markets usually at high prices, with a small proportion left for home use and for seed. Farmers commonly use their own seeds for the following planting season.

The by-products of haricot bean are used for livestock feed in the dry season. Farmers carefully store the haulms near homesteads so that the neighbouring animals do not have access to them. Stacking protects from the rain.

Package Testing

Packages developed at Nazreth Research Centre were tested in farmers' fields since 1980. The bean package included an improved variety, Mexican 142, proper land cultivation, proper time of planting and optimum weeding. No fertilisers were used as part of the package. For this study farmers provided a hectare of land and labour for managing the trial whereas the research centre provided the improved variety and technical supervision.

The programme was run for four years (1980-1983) and a yield increase of about 150% over the traditional yield was achieved. Though high yield increase was obtained, farmers were reluctant to accept the complete package. Rather, they chose only the improved variety and followed their traditional way of production. The main reason for not accepting the rest of the package was overlapping of different activities. To date, it is not uncommon to see the improved variety, Mexican 142, being grown by the farmers in the region.

Table 2 summarises the outcome of the package testing programme in haricot bean. As indicated in the table, farmers can increase their yield of haricot bean to 1500kg/ha. To date, farmers obtain only about 600kg/ha.

On-Farm Verification Trial

In 1986 an on-farm variety verification trial in haricot beans was conducted on farmers' fields. The main objective of the study was to evaluate some new haricot bean varieties for their adaptability to the local climatic and management conditions and farmer preferences. Here the farmers' involvement was encouraged in carrying out and managing as well as evaluating the trial.

The trial was superimposed on the farmers' method of production. Four new varieties of haricot bean and the standard check, Mexican 142, were planted at five locations. The crop was planted adjacent to the farmers' haricot bean fields. In some sites the sowing date was made to coincide with that of the farmers. In other sites these were planted in the same week.

The trial was designed in a randomised block. Sites were taken as blocks and the varieties were randomised among plots in each site. A plot of $100m^2$ was used for each treatment.

Data were collected on yield and plant population, both from the trial and farmers' own fields. Almost all farmers produce Mexican 142. Plant height and number of pods per plant were recorded. Generally, yields obtained were very low (Table 3). This could be attributed to the rainfall condition, which was poor in the area, and heavy weed and disease infestation. Responses of the varieties at different sites, however, were different and ranking of varieties differed from that found in trials on the station. There were statistically significant differences among farm location means. These could be due to differences in management and environment. Statistically significant yield differences were observed among varieties ($P \leq 0.1$). The variety W-108-0177-27 gave the highest yield at two locations. Sample yield taken from farmers' fields was the highest at three locations and also second across location. The other variety that had better performance was W-117 (01504). Varieties W-108-0177-27 and W-117 (01504) had better resistance to rust. Variety W-117 (01504) was also found to have good resistance to bacterial blight.

The plant population on the farmers' plot was twice as much as that of the experimental plots, and the farmers' beans were

Table 2. Summary of Technical and Economic Data on Package Testing with Haricot Bean (Mexican 142) 1980/81-1983/84.

Technical Data	1980/81	1981/82	1982/83	1983/84	Average
Yield (kg/ha)	1391	1380	2000	1296	1517
Seed rate (kg/ha)	58.00	55.00	65.00	56.00	58.50
Ox-pair hours (hrs/ha)					
Cultivation	96.53	71.03	81.65	63.70	78.23
Threshing	53.30	32.33	56.00	55.80	49.36
Total	149.83(1)	103.36(2)	137.65(3)	119.50(3)	127.59
Man hour (hrs/ha)					
Land preparation and planting	120.14	88.53	94.50	75.70	94.72
Weeding	162.61	149.33	74.00	-	128.62
Harvesting and transporting	117.58	91.50	217.83	167.00	148.47
Threshing and winnowing	76.33	31.83	66.80	38.20	53.29
Total	487.66(2)	361.24(2)	443.13(3)	280.90(3)	425.11
Economic analysis					
Assumed producer price (Birr/kg)	0.43	0.80	0.20	0.50	0.48
Value of production (Birr/ha)	598.13	1104.00	400.00	648.00	731.95
Direct Costs (Birr/ha) Seed	24.94	24.75	13.00	28.00	22.67
Total Direct Cost	24.94	24.75	13.00	28.00	22.67
Gross return (Birr/ha)	573.19	1079.25	387.00	620.00	709.28
Gross return (Birr/m.h)	1.18	2.99	0.87	2.27	1.67
Imputed cost (Birr/ha) Cost of labour, oxen)	191.96	164.22	227.32	168.28	198.57
Net return (Birr/ha)	381.23	915.03	159.60	451.72	510.71

(1) Farm labour and oxen pair costed at a rate of 0.24 and 0.50 birr/hr respectively.
(2) Farm labour and oxen pair costed at a rate of 0.24 and 75 birr/hr respectively.
(3) Farm labor and oxen pair costed at a rate of 0.28 and 0.75 birr/hr respectively.

also performing as well or better than the new varieties. This might be due to the high level of plant population observed in farmers' haricot bean fields.

In the 1986 crop season a recommended seed rate which was much less than the farmers' rate was used. In the 1987 on-farm verification trial the seed rate will increase to the farmers' rate of seeding and the number of testing sites will increase in order to have more reliable data. Moreover, farmers' involvement will be encouraged to a higher degree.

At the research center a research programme has now been initiated by the Agronomy Research Division with the objective of determining appropriate seed rates based on the problems identified during on-farm trials and farm surveys. The effects of erect and prostrate growth habits in potential new varieties are also being examined, due to our observations on farmers' management of weeds.

Table 3. Haricot Bean Verification Trial. Data Summary 1986.

	On-Farm Means		
Treatments/ Varieties	Yield kg/ha	Plant Population	Yield in kg/ha on-station
W-108 (0177-2)	453	240,000c	1,020
W-95-08	307	248,000c	1,533
WR-375-08	331	240,000c	1,353
W-117 (01504)	404	256,000c	1,008
Mexican 142	365	304,000c	961
Farmer sample	448	424,629a	-
LSD 10%	93.0	66,867	
5%	NS	80,861	
SE	±38.1	±27,410	
CV%	22.16	21.47	

NS. Non-significant at the indicated probability level. Means followed by the same letter do not differ significantly at 0.05 probability level using Duncan's New Multiple Range Test.

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29792

Methodology and Results of Diagnostic Trials on Common Beans in Rwanda: A Critical Appraisal

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Introduction

Diagnostic trials play an important role in the diagnostic process of crop improvement programmes when informal and formal surveys do not provide enough information to quantify the identified problems nor their relative importance (CYMMIT, 1980; CIAT, 1985). In Rwanda, surveys indicated that diseases, insect pests and low soil fertility may be the most limiting factors for bean yield. However, it was not clear which factor should get first priority for technology development nor whether there are interactions between these factors which should be considered. For these reasons the national bean programme of the Institut des Sciences Agronomiques du Rwanda (ISAR) in collaboration with the regional bean programme of CIAT decided to start a series of diagnostic trials in several major bean producing areas of Rwanda.

Material and Methods

Trials were carried out from the second season of 1984 to the second season of 1986 in six natural agricultural zones of Rwanda with the primary objective of quantifying the contribution of the three major limiting agronomic factors described above to reduction of bean yield. Other important factors such as drought and acidity were not included because it was judged that it would be difficult to generate appropriate technologies to control them. Table 1 gives a summary of factors included in the trials and the treatments to control them.

The trials had to be carried out on farmers' fields because no representative experimental stations were available in some areas and it was judged that direct interaction with farmers would help to guide research.

Due to small farm size, a complete factorial design including eight treatments was not appropriate since at least two replications per farm are required for this type of trial. Consequently three designs, "Plus one", "Extended plus one" and "Minus one", were used. They are described in Table 2. Plus one designs add alternatives to a traditional method; the alternatives in this case were fertilisers, fungicide sprayings/soil treatments and insecticide sprayings/soils treatments. The effect of each treatment is simply measured as increase over farmer's practice which is included as a treatment.

Table 1. Factors Included in Diagnostic Trials on Beans in Rwanda.

Factor	Treatments	Code
Fungal Diseases	Soils treatment: Benlate 25kg/ha Ridomil 5kg/ha Foliar treatment: (weekly) Benlate 1.1kg/ha Copper oxychloride 4.4kg/ha (-86A) Copper hydrochloride 4.4kg/ha (86B)	A
Pests	Soil treatment: Carbaryl 1.5kg/ha Foliar treatment: Dimethoate 1 l/ha	B
Soil fertility	Cow manure 40t/ha Diammoniumphosphate (at stage V3) 110kg/ha	C
Diseases + Fertility	A + C	A + C
Diseases + Fertility + Pests	A + B + C	D
Farmers' practice	-	E

In the Extended plus one design, an extended treatment was added to the basic set, combining the two factors most likely to interact with each other (in our case fungicides and fertiliser). The third design was a Minus one design, which is the opposite of a Plus one trial. Added to a standard farmer's practice were a treatment controlling all factors at one time and three treatments where the control of two factors is combined. The contribution of one factor is calculated by deducting the yield of the treatment where the factor is not controlled from the yield of the treatment where all factors are at optimum level (de Datta, *et al.* 1980; CIAT, 1985).

In general, the trials were conducted at three to four farms per region with two replications per farm. Observations were made regularly on plant vigor, density and especially disease incidence. Differences between plots were discussed with farmers in order to get an idea about their knowledge of effects of fertiliser and disease/pest control.

Table 2. Comparison of Trial Designs Used for Diagnostic Trials on Beans in Rwanda (1984-1986).

Treatments (Control of)	Designs		
	Plus one	Minus one	Plus one extended
Diseases	+		+
Pests	+		+
Fertility	+		+
Fertility + Diseases		+	+
Fertility + Pests		+	
Diseases + Pests		+	
Diseases + Pests + Fertility		+	
Farmers' practice	+	+	+

Results

Yield data from four seasons' trials are summarised in Table 3. Plus one trials suggest diseases to be the most limiting factor, whereas results from Minus one trials suggest that low fertility and diseases are of almost equal importance (Figure 1). Yield increase due to control of pests is estimated by both designs to be in the magnitude of 150 to 250 kg/ha. In 1986B a further comparison in one area of Minus one trials with Plus one extended trials underestimated the effect of fertilisers; but the treatment with combined fungicide/fertiliser application revealed a tremendous positive interaction between those two treatments (Table 4).

However, the interaction can also be estimated from the Minus one design. If the addition of all the calculated contribution exceeds or is less than the difference between the optimal treatment and farmer's control, an interaction between at least two of the tested factors must be present. In the case of the trials in Nyabisindu, the addition of the calculated yield increases due to the control of the three factors adds up to 3,071 kg/ha; this is more than the difference between potential yield and farmer's yield, which is 2,497 kg/ha (3,497-1,000 kg/ha). This is suggestive of a negative interaction between factors and not a positive one as we found in the Plus one design.

Table 3. Yield advantage obtained through control of diseases and pests and optimization of fertility using both minus and plus one designs in on farm exploratory trials in Rwanda.

NATURAL REGION	Altitude (meters)	Season	Trial Design	Control of Diseases (kg/ha)	Control of Pests (kg/ha)	Augmentation of Soil fertility (kg/ha)	Reduction of Acidity (kg/ha)	Farmer Control kg/ha	Combined treatment	% Over Farmer Control
				YIELD ADVANTAGE RELATIVE TO FARMER CONTROL						
Zaire-Nil		85 b	Plus[1]	556	623	489	334	444	-	
Crest	2100	86 a,b	Minus[2]	381*a	150	605*;a,b	-	1008	1508* a b	150
Buberuka		85 b	Plus[1]	556*b	-200	-156	-67	1500	-	
Highlands		86 a,b	Minus[2]	401*a	18	588*,a	-	825	1884*,a,b	228
Central Plateau		85 a,b	Plus[1]	640*a,b,b	190*,b	250	98	981	-	-
and	1700	86 b	Plus[1]							
Granitic Spur		86 b	Minus[2]	719*,b	95	906*,b	-	987	2935*,b	297
Central	1900	86 b	Minus[2]	46	9	242*,b	-	375	675*,b	180
Plateau	1800	86 b	Minus[1]	550	150	567*,b	-	833	1867*,b	224
Mayaga	1400	85 b	Plus[1]	493	166	240	193	267	-	
		86 a,b	Minus[2]	299*,b	104	399*,b	-	1051	2056*,a,b	196
Lake Kivu Shore	1450	86 b	Minus[2]	967*,b	434	667	-	1133	2900*,b	256
Bugesera	1200	85 a	Plus[1]	-9	297	8	-84	628	-	
Mean		85	Plus[1]	447 (59%)	233 (31%)	166 (22%)	112 (15%)	764	-	
		86	Minus[2]	497 (52%)	158 (17%)	566 (60%)	-	-	949 1995	(210%)

* a = Significantly different (P = .05) from farmer control in season A
* b = Significantly different (P = .05) from farmer control in season B
1 = Y factor - farmer control = Yield advantage
2 = Combined treatment - Y factor = Yield advantage

In the Minus one trial series in the zone of Mahaga the combined analysis over two seasons again shows another set of possible relations between the factors tested (Table 5). The calculated effects of the three factors add up to 1,039 kg/ha; meanwhile, the difference between optimum treatment and farmer's control is 1,084 kg/ha. In this case no interaction seems to occur. Similar calculations could be done for all the other areas, and one could develop various hypotheses on types and magnitudes of interactions.

Table 4. Diagnostic Trials on Beans in Rwanda: Comparison of Yield Data from Minus one and Plus one Trials, Nyabisindu, 1986B.

	Yield advantage (kg/ha) over control as measured by:	
Factors controlled	Minus one	Plus one ext.
Diseases	1399*	677
Pests	169	151
Fertility	1591*	308
Fertility + Diseases	2327*	1765*
Fertility + Diseases + Pests	2497*	-
Farmers' practice	1000	633
LSD (0,05)	505	355

<u>Interaction Fungicides x Fertilisation:</u>

Calculated additive effect: 308 + 677 kg/ha	=	985 kg/ha
Yield advantage in trial	=	1765 kg/ha
Effect of positive interaction:		780 kg/ha

*Effect significant over farmers' practice at p = 0.05

Discussion

The various designs tested all have advantages and disadvantages. Plus one designs permit estimation of the potential effect of technologies developed to control one single factor, e.g. diseases. They are easier for farmers to understand and therefore facilitate the interaction between farmer and

Table 5. Diagnostic Trials on Beans in Rwanda: Yield data from Minus one Trials over two seasons and calculated contributions of limiting factors to total difference between potential and actual yield (Mugusa, 1985/86)

Treatment	Yield (kg/ha)	Difference from optimal treatment (kg/ha)
Fungicide + Insecticide + Fertilization (A + B + C)	1959a	----
Fungicide + Fertilisation (A + C)	1834ab	125
Insecticide + Fertilisation (B + C)	1616bc	343
Fungicide + Insecticide (A + B)	1388c	571
Farmers practice (E)	873d	1086

<u>Contributions of factors to total differences D - E (kg/ha)</u>

Fertility (D - [A + B] :	571
Diseases (D - [B + C]:	343
Pests (D - [A + C]:	125

LSD (0.05) = 310.5 , CV = 17.86%

Total calculated:	1039
Difference in trial (D - E):	1086

LSD (0.05) = 310.5 CV = 17.86%

researcher. On the other hand, they are of limited help in directing a research programme when they neglect a potentially important factor because of interactions with another factor, as demonstrated in the example of soil fertility in Rwanda.

Minus one designs give interesting information on the potential yield increase through control of the major limiting factors. This may be important for policy-making. In Rwanda the Plan alimentaire is assuming a 100% increase in bean yields by the year 2000. The maximum yield plots in the Minus one trials just reached this 100% increase with all inputs at optimum level. This makes the assumption look rather unrealistic. Minus one designs are also more likely to identify an important limiting factor, such as soil fertility in Rwanda. Important disadvantages are the complex design, especially for trials conducted on farmers' fields where the number of factors should not exceed three or a maximum of four factors (because of hidden interactions in the combined treatments).

Sometimes there is a problem of underestimating the potential benefit of the control of a factor because of measuring the contribution of the factor to yield loss at high levels of other inputs. Bean fly attack, for example, is known to have less effect on yield at high levels of fertility (Autrique, pers. comm.). It is also difficult to estimate the potential benefits of future technologies if they are not applied as a package. This disadvantage, on the other hand, is lessened by the fact that one can target technologies towards a situation where other factors are controlled. In Rwanda, applying fertiliser to climbing beans may be more promising than applying it to bush beans because climbers can escape the microclimate favouring disease development. Disease-resistant varieties may be first recommended for more fertile plots since they are more likely to express their potential at higher fertility levels.

Minus one designs extended by one combined treatment are a good solution when there is a strong hypothesis as to what factors would most likely interact. Otherwise the number of treatments approaches the number of treatments in a complete factorial trial because one has to combine the control of various factors. Without such a hypothesis, the powerful complete factorial design should be chosen.

Summary and Conclusions

On-farm diagnostic trials were carried out in six natural zones of Rwanda between 1984 and 1986. Three designs were used: Plus one, Minus one and Plus one extended. Plus one trials tended to underestimate the importance of soil fertility as a yield-limiting factor but showed clearly the importance of diseases. Minus one designs made the importance of both factors visible, and Plus one trials showed a strong postive interaction when disease control was combined with fertiliser application. However, none of the described designs is able to completely explain the interactions between tested factors.

Given the advantages and disadvantages described above, the researchers who carried out these trials in Rwanda would recommend that if diagnostic trials are necessary in an area, a considerable effort should be made to find representative sites off-farm (schools etc.) to permit the installation of complete factorial trials. In addition, several Plus one trials could be established on-farm which would result in a combination of a powerful design and trials which make the interaction with farmers easy and permit direct conclusions on the potential effect of new technologies and their interactions. Plus one designs alone may be appropriate when no interactions are expected, but in this case one should seriously think of testing different levels of a treatment and consider the trial as a step in technology testing rather than as a diagnostic trial. The methodology to use obviously depends also on resources available to the research programme.

For Rwanda, it is recommended that the research programme focus on technologies which control both diseases and fertility at the same time or to target technologies to situations where one factor is controlled through existing practices such as disease control through the use of climbing beans. Technologies to control pests should have lower research priority but do play an important role in some areas. Therefore, it may still be justifiable to carry out research on pest control technologies which seem to be easy to generate and to diffuse, such as seed treatments against bean fly with endosulfan (Trutmann *et al.*, 1987).

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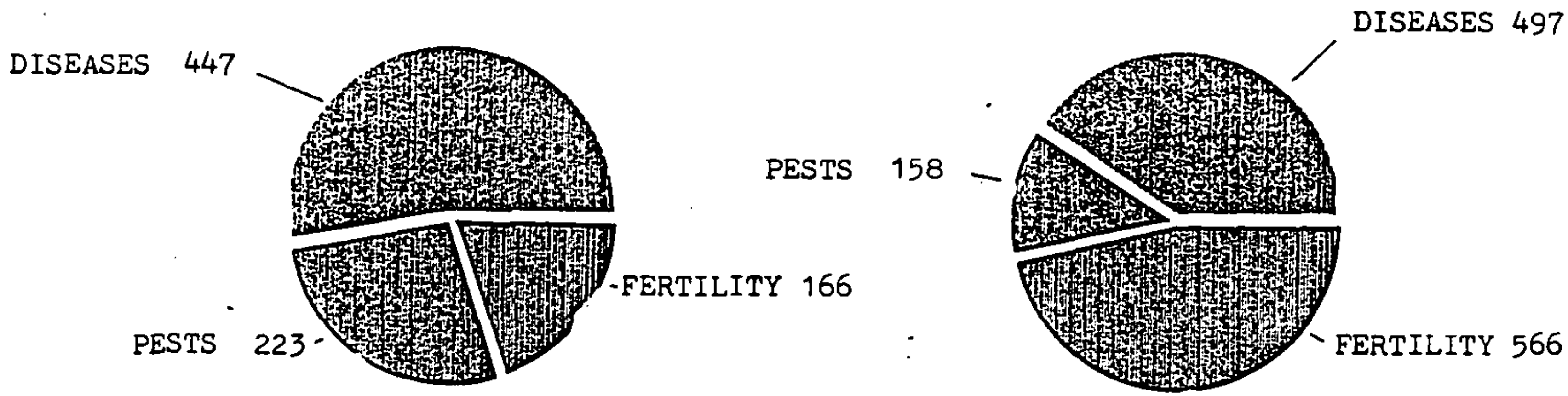
FIG 1: DIAGNOSIC TRIALS IN RWANDA ON COMMON BEANS: YIELD INCREASES RELTIVE TO FARMERS PRACTICE THROUGH CONTROL OF PESTS, DISEASES,AND LOW FERTILITY MESURED WITH "PLUS ONE" AND "MINUS ONE" - TRIALS (KG/HA)



"PLUS ONE" - TRIALS

"MINUS ONE" - TRIALS

The Need for Establishing a Research-Extension Linkage

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Introduction

Uganda is an agricultural country whose economy depends on agriculture; therefore, economic development should result from agricultural development. The latter can hardly take off unless new agricultural technologies and innovations are generated and then transferred to the producers (farmers) for utilisation in the development of their farming operations.

In Uganda, the Department of Agriculture has a well-established, good stock of research results, though disrupted by civil war. It also has a well-established extension system. There is only one problem and that is the lack of extension-research linkage. The gap between research and extension slows down the technology and innovation transfer, hence the need to bridge the gap by establishing research-extension linkage. Mindful of this necessity of the linkage between research and extension, the Department of Agriculture posted an agricultural officer in agricultural research to serve as a research-extension liaison officer as far back as 1970. However, the liaison officer had no definite duties and there was no establishment of the post. This meant that if the incumbent left the place, it was difficult to appoint another officer in the same post. This situation has continued to persist.

Research-Extension Linkages

Agricultural extension and agricultural research depend on each other if they are to accomplish their roles. The responsibilities of research and extension personnel at all levels can best be carried out if they communicate regularly, consider mutual problems and opportunities co-operatively and make every effort to co-ordinate their programmes. A demonstrated ability to communicate effectively at all levels will have a positive influence in the Department of Agriculture.

Linkage occurs when one or more members or at least two groups relate themselves in such manner that the groups in some ways, on some occasions, may be viewed as single group. That is, the linkage should be such that research and extension function as one complementary unit before or with farmers and the public at large.

These linkages are important for many reasons. New technology adoption is a corner-stone in most agricultural development strategies. Since various functions of agricultural technology development and the utilisation system have been assigned to various agencies, linkage must occur for the technology to be utilised.

There is need for research to involve extension workers and farmers in the diagnosis and definition of farmers' problems and proposing research approaches. There is need for the research workers to have feedback from the extension personnel, farmers and other users. There is need for researchers to be directly involved in the training of extension personnel and in updating the knowledge and skills in new or changing recommendations.

Internal Linkages

Internal linkages are found at the following levels:

a) Commodity research and adaptive area research,
b) Field extension workers and subject matter specialists,
c) Adaptive area research and field extension workers,
d) Commodity research and field extension workers,
e) Commodity research and farmers,
f) Farming systems research.

External Linkages

a) Departmental commodity research and university commodity research,
b) University commodity research and adaptive research as well as farming system research,
c) Extension and agrio-business sector,
d) Adaptive area research and agrio-business research,
e) Departmental research and international research.

Proper and smooth liaison of the two types of linkages can bring about and speed up agricultural development.

General Issues of Effective Linkages

There should be a shared role. All the parties concerned with agricultural development should have the same objectives and implement them mutually. That is, each should have a portion in the development of the farmer and farm business in a joint venture.

There should be common agreement on philosophy and approach. All the agencies concerned with agricultural development should

Figure 1. Agricultural Technology Development and Transfer Continuum

Needs/ Problems	Basic & Applied Research	Technology Generation	Technology Testing	Technology Adaptation to various conditions	Technology Integration in farming systems	Dissemination to farmers	Diffusion & Adoption

<u>Situations</u>

```
  1. Commonly assigned Commodity
     research and Extension
     functions leave a gap
                          Research                                                                     Extension
     xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx  The GAP                xxxxxxxxxxxxxxxxxxxxxxx
--------------------------------------------------------------------------------------------------------------------------

  2. Adaptive Research fills the
     gap but has no overlap with extension

     Commodity Research
     xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

                              Farming Systems Research                                               Extension
                              xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx   xxxxxxxxxxxxxxxxxxxxx
--------------------------------------------------------------------------------------------------------------------------

  3. Commodity/Research, Farming
     System Research and Extension
     linked by on-farm research

     Commodity Research
     xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

                                      Farming Systems Research
                        xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

                                                                                     Extension
                                                                 xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
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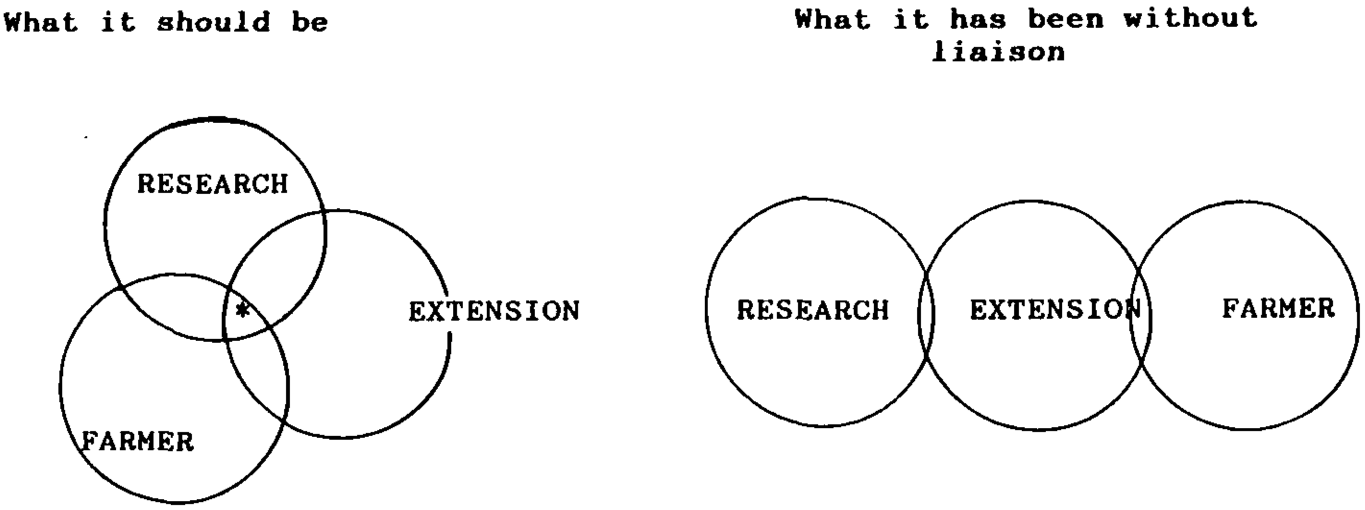
Figure 2. How Situation 3 (Fig. 1) Appears in the Field



* The situation brought about with Liaison.

share the same philosophy and approach necessary to promote agricultural productivity and production.

Common understanding of the content and needs involved in the linkage is necessary. Planning together in an integrated manner brings about this phenomenon.

Organisational means are required to foster effective linkage. The set-up should be such that it facilitates effective communication, harmony and smooth co-ordination.

Staffing is needed for improved linkages. The linkage should be manned by experienced, senior and qualified personnel capable of effecting the required effective and efficient linkage.

Farming Systems and Adaptive Research.

Farming systems research is diagnosis of the on-farm operations under the farmers' farming patterns and definition of on-spot improvement or modification to be made therefrom. Adaptive research is the testing of basic or applied research results in the farmer's environment to see whether such results are adaptable to the field conditions. The combination of these two types of research is very useful in that it brings the researchers, extension personnel and farmers together to diagnose farm problems and define solutions and strategies for accelerating agricultural development.

Figure 3. Four Structured Stages Understanding Farmers' Problems and Producing Acceptable Recommendations

Leading Actors		
	ZONING	Group Farmers by their farming activities into different farming systems.
Agric. Economist Rural Socio-logist Biometrician Agronomist Ex.specialist	SURVEY Informal Formal	Study the constraints of each farming system to understand the farmers' problems and identify thei potential for development.
Everyone is involved	RESEARCH PRIORITIES DESIGN	Applied and adaptive research which will aim at solving the most important technological problems identified in the farming system.
Agronomist	ON-FARM TESTING	Test and, if necessary, modify research solutions on farmers' realistic conditions until acceptabl solutions are found.
Research/ Extensionr Liaison Officer	RECOMMENDATIONS	Produce recommendation for the system.

Linkage Constraints

Organisational Constraints

a) Lack of zone of common goal
b) Difference in gains to be achieved
c) Lack of agreement on degree and location of linkage
d) Differences in philosophy: How to do the job
e) No focal points for links
f) Needs for organisational identity and credit
g) Lack of initial respect
h) Specialisation; loss of identity with larger goals of organisation
i) Lack of policies of links
j) Lack of procedures and mechanisms
k) Force of tradition, routine
l) Lack of interaction between related organisations including feedback from the farmer

Educational Training Constraints

a) Differences in training and skills
b) Superiority and inferiority complexes
c) Terminology differences from discipline background
d) Poor communication skills
e) Lack of application for linkages
f) No understanding of what can be gained of officers

Human Factors and Attitude Constraints

a) People with less education, experience not valued for linkage
b) Personal trials of supervisors; loyalty issues
c) Personal conflict, jealousies

Resource Constraints

a) Lack of operational funds to support links
b) Inadequate staff and training of key linkage personnel; subject matter (subject matter specialists).

Other Constraints

a) Physical distance (between research and extension personnel)
b) Lack of interaction; all related organisations and farmers
c) Lack of policy development
d) Lack of staff exchange
e) Lack of appreciation of farmers and mechanism for feedback, small and large scale
f) Mixed administrative and technical responsibilities
g) Lack of farmer organisation involvement

h) Lack of internal and external linkages

Linkage Problems

Lack of Common Goals

a) Lack of common policy on research and extension
b) Common goals for research and extension not spelled out
c) Common planning teams at national level lacking

Lack of Farmer Involvement and Respect (Feedback)

a) Involvement of farmers and wives in field days and incorporating them in societies still absent
b) Involvement of farmers in training session, e.g. regional workshops, still non-existent
c) Inviting farmers for meetings by field staff and supervisors still a bottleneck

Differences in Training and Skills

a) Low cadre of agricultural staff are better trained in skills than those in the higher cadres and this brings conflict
b) Lack of human relations training for researchers and extension officers
c) Lack of screening for potential extension workers for effective communication, motivation and dedication by the training committee

Lack of Operating Funds

a) Lack of equitable allocation of funds to both extension and research
b) Research and extension do not have mutual sharing of resources

Lack of Procedures, Mechanics and Policy

a) There is no direct communication between lower extension workers and researchers
b) Lack of written guidelines on policy and procedures for linkage
c) Consultation and meetings between researchers and extension officers through workshops/seminars do not exist

National and District Committees

In order to overcome the above stated constraints and problems, there is need to establish a National Agricultural Research Council and District Agricultural Committees.

The National Agricultural Research Committee should be charged with the responsibility of working out the research and extension policies, strategies and guidelines. The membership should include the Minister of Agriculture, the Permanent Secretary, The Commissioner for Agriculture, the Chief Research Officer, The Dean of the Faculty of Agriculture, the Permanent Secretary (Ministry of Planning and Economic Development) Farmers' representative, District Agricultural Research Committees representatives.

The main function of these committees should be to ensure co-ordination of research and extension activities in the provinces. The membership at the District should include the District Agricultural Officer, Chairman, the agricultural officers in charge of counties, Faculty of Agriculture representatives, members of the Adaptive Research Planning Team, subject matter specialists and farmers' representative.

The following steps and procedures will enable the abovementioned committee to carry out duties as planned and in a systematic way.

- Deliberately establish a favourable "Family" environment.
- Policy statement of mutual support. (Include in objective statements and job descriptions.)
- Develop a memorandum of understanding; provide continuity.
- Develop procedures for implementing the policy or memorandum.
- Hold regular meetings at least twice yearly.
- Set up joint committees to monitor and articulate recommendations.
- Joint field days.
- Set up similar organisational structures.
- House research and extension counterparts near one another.
- Set up joint adaptive research and demonstration teams.
- Provide personnel with mobility and capacity to publish teaching materials and aids.

Conclusion

The need to establish a research-extension linkage cannot be over-emphasised. The linkage between research and extension is necessary and urgent in order to get agriculture moving.

The ideas expressed in this paper are meant to stimulate thinking and discussion on those points necessary to promote the establishment of a viable and effective research linkage that will facilitate technology-innovation transfer. to the farmers in order to promote agricultural development.

SUMMARY OF DISCUSSION

Socio-economists have an important role to ensure that farmers' problems, objectives and resources are included in planning trials. Understanding farmers adequately requires a whole-farm perspective.

On-farm trials are part of the search for the best technology, and should therefore include technologies (including varieties) that are not yet fully proven as the best. Testing alternatives on-farmers' fields with their participation is the most efficient way to identify best technology for farmers. Research stations will continue to be tremendously important, e.g. in creating and screening genetic diversity, of which perhaps less than 5% will be considered worth taking to farms for final selection to be made.

Economic analyses and farmer assessments may still be worth making even when there is no statistically significant difference between treatments in an on-farm trial. If farmers only grew beans when they were 95% certain of a profit, there probably would be no beans in the world! Followup of participating farmers may be needed the year after the trial to see if farmers have continued or not with the new technology, and why. This followup complements farmer-managed trials, and is still part of the research process, not extension. However, there may be advantages in having some involvement of extension.

The importance of intercropped beans in bananas in Uganda suggests a need to investigate shading and other interactions in this association.

SESSION III: GENETIC IMPROVEMENT OF BEANS

Evaluation and Utilisation of Bean Germplasm at Kawanda, Uganda

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Abstract

The climate in most parts of the country favours bean growth and production in Uganda. The major constraints to production have been found to be pests and diseases, lack of inputs, credit system, varied soils and infrastructure plus lack of improved varieties and low market incentives. Great genetic variation for the major characters considered by breeders was found in the existent germplasm, but even more is found in the introductions. Many introductions depicted high levels of adoption to the conditions in the country, thus making advances to new variety releases easier and quicker.

Introduction

Uganda forms part of East Africa and lies astride the Equator. It has an area of about 236,000 sq. km., the land surface being approximately 194,000 sq. km. The remainder is essentially lakes with Lake Victoria being the largest body of water (Anon., 1957).

The country has two main distinct seasons, the wet and the dry. The wet season in central, western and parts of eastern Uganda lastd from March to June and September to December. In these areas there are short dry spells between January and March and July to August. These seasons favour continuous bean crop growth in most parts of the country where rainfall ranges between 750 mm and 1000 mm per year. But in some parts of the country, such as Kidepo, the rains are erratic and badly distributed.

More than 80% of the country lies between 1000 m and 2500 m above sea level. This elevation results in a temperate climate for most of the country (i.e. 15°C to 25°C in the extreme north). The temperate climate plus continuous cropping makes diseases one of the major production constraints of beans (Jalil, 1973; Schoonhoven, 1980; Zaumeyer and Thomas). Beans form one of the major sources of protein in the world and East Africa is one of the major production zones (London, 1980).

In Uganda, bean production acreages are second only to those of staple foods such as plantains, millet, maize and sorghum. This has helped to reduce the child malnutrition that has escalated in previous years, especially in the banana/cassava-growing areas (Anon., 1971). Bean cultivars grown in Uganda take between 70 and 90 days to mature (Mukasa, 1970). Spread of most bean diseases is between the primary leaf stage and the drying stage. With continuous cropping, these stages exist almost throughout the year, making disease inoculum available all the time. Breeding for disease and pest resistance and the production of new and improved higher yielding varieties, therefore, becomes an important undertaking. Studies on this crop have, however, shown that seed size, seeds per pod and pods per plant are the most important yield components. Seed size shows high negative indirect effects via seeds per pod and pods per plant. Selection for high yield, therefore, is done for a combination of these characters instead of selection for yield itself (Adams, 1967; Adams and Grafius, 1971; Durate and Adams, 1972). The breeding material at Kawanda is made up of two categories, local and exotic sources of germplasm.

Local Sources of Germplasm

The collection of bean germplasm continues to be one of the major objectives of the breeding programme. By 1984 there were two main sources of local germplasm. One source was the germplasm collected by S. Mukasa. Many lines from this source lost viability due to lack of proper storage facilities and disturbances of the war in 1982. A collection was then carried out from the western parts of the country in July 1984, but some lines were lost due to the turmoils of the war in 1985. Only 240 lines survived and form part of the collection.

There are plans of carrying out a random collection of materials from the same areas with the hope of re-collecting those lines that were lost. Originally, under the two breeders, D. Mulindwa and N. Wanyera, the collection was divided into haricot (126 lines) and French beans (164 lines). Some members of this original collection were introductions from CIAT, USA and Europe. This material, together with the western collection, make up a total of 550 lines.

Exotic Sources of Germplasm

The recent introductions added to the germplasm are mainly of CIAT origin (see Table 1). It was only in August 1986 that some materials were collected from Rwanda and Tanzania (Morogoro). The CIAT materials came into the country in the form of the IBYAN, IBRN, VEF and different disease nurseries. AFBYAN trial also introduced a few varieties. These are sent to us either on order or when CIAT wants to try the nursery in Uganda.

Table 1. Status of Bean Collection Held at Kawanda as per December, 1986.

	Introductions (Mainly from CIAT)	Local sources (Western and S. Mukasa's)	Total
Original No.	225	530	755
Existing No.	166	384	550
Lost	59	146	205

The above germplasm was evaluated for several aspects in the breeding plots.

Materials and Methods

The germplasm was planted as double rows of 4 m length per entry. The spacing used was 60 x 10 cm and no fertilisers were added. In the yield trial a completely randomised design was used with three replicates per entry. Each plot consisted of six rows of 4 m length at the same spacing as for the germplasm. Observations and yield were taken from the two central rows in each plot. The entries in the trial consisted of seven introductions and four local varieties. The introductions used were selected from CIAT material that performed relatively well in earlier evaluations as per Table 4.

The routine data taken included germination counts, stand counts, flowering dates, vigour, days to maturity, plot yields, 100 seed weight and reaction to the major diseases i.e. anthracnose, common bacterial blight (CBB), angular leaf spot (ALS), rust, BCMV and ramularia, using a 1-9 scale.

The introductions in the yield trial together with several local varieties were tested for cooking time using the Mattsen Bar-Drop Cooker. Introductions A-162, BAT 1220 and nine local varieties were tested on their moisture uptake over a period of 1, 2, 3, 4 and 14 hours. This was done by pre-weighing, soaking in distilled water for a specified time and taking the weight of the soaked beans.

Results and Discussions

Disease Reaction

Combined analysis of the Kawanda germplasm as per December 1986 showed variations in disease reactions with respect to some diseases as per Table 2.

Table 2. Reaction of Kawanda Germplasm to Some Diseases.

Disease	CIAT origin Nos. and levels of resistance			Local Collection Nos. and levels of resistance		
	S	I	R	S	I	R
Common Bacterial Blight	4	15	125	10	72	19
Anthracnose	0	2	142	42	45	14
Rust	48	57	49	54	31	16
Black rot	31	0	144	Not observed		
Angular leaf spot	32	25	87	14	52	35
Total	113	99	547	120	200	84

S = susceptible, I = intermediate, R = resistant

Results in the above table indicate that a great deal of variation to disease reaction was existent in the collection. More genes for resistance to the major diseases were, however, depicted in the introductions than the locally acquired germplasm. This justified the acquisition of more introductions as a source of variation for utilisation by the breeders. However, as the above observations were made under non-inoculated conditions, indications of "resistance" should not be taken with the confidence that would be necessary for use as parental material.

Seed Colour

Market surveys in the country showed that seed marketability and acceptability are normally based on the seed colours and sizes of a given variety. These characters are, therefore, emphasised in the present breeding programme. The present germplasm was found to be highly variable for this character (*Fig. 1*).

For the germplasm that existed as per 1986, the highest colour percentage was among the reds followed by the whites. For the Eastern collection made early this year, less variation was observed in colours than in the sizes. Highest percentage of seed in the total collection was among brown, followed by reds and whites. Generally, the colour variation was higher among the introductions than in the local collection, thus showing preferential selection for colours among the farmers.

Plant Habit

There is variation in growth habit of the germplasm at Kawanda as shown in Table 3.

In the highlands where staking material is not a problem, climbing varieties are preferred since they are higher yielding and have an extended harvest period, thus supplying fresh pods for family consumption over a longer period. In some areas staking is avoided by intercropping the climbers with sorghum, young bananas, maize, cassava etc. which act as supporters of the bean crop. The climbers also generally are not liked in other areas due to the following disadvantages they possess:

(a) They stay in the field and therefore are problematic in areas where there is land scarcity and more crops per year need to be grown.

(b) They need stakes which may be scarce or the possible staking material is preferably used for fuel.

(c) Their harvesting is continuous and cannot be synchronised, thus making them more labour-intensive.

Table 3. Variation in Growth Habit in the Germplasm at Kawanda.

Growth habit	No. of accessions	Percentage
Bush (Habit 1-2)	293	37.8
Climbing (Habit 3-4)	482	62.2
Total	775	100.0

The breeding programme aimed mainly at producing bush type beans, but there are future plans to select for climbers to be recommended in areas where staking is not a problem.

Utilisation

Yield and Adaptability

Generally, yields fluctuate considerably, and at times farmers may get total crop failure (Mukasa, 1970). In most cases the yield of varieties is offset by their reaction to the prevailing diseases as is evident in Table 4. The local varieties were very susceptible to angular leaf spot, rust and common bacterial blight. Seasonal variation in yield was also observed among varieties, though some of the introductions such as CARIOCA and CATU showed stability against the seasonal changes.

The varieties selected from germplasm after previous screening also showed much variation in their yield. The yield trial was carried out in Bukalasa which has a slightly different soil type compared to Kawanda. The results in Table 5 show variation in the yields of different varieties.

The highest yielder, BAT 1220, was significantly different from the rest of the entries. The six introductions were apparently higher yielding than K 20 but not significant from it. CATU, CARIOCA, A-162 and BAT 1220 were significantly different from our local popular variety, Kanyebwa. BAT 1220 is red and medium size, having similar colour to one of the land races called Kainja. Therefore, it can easily be acceptable on the market in eastern, central and western Uganda. The rest of the introductions are cream coloured and can only be taken on by some farmers in eastern, central and western Uganda but can easily be acceptable in north and north-eastern Uganda.

In 1984 a total number of 356 entries VEF materials were introduced. Of these, 59 entries showed best adaptation for yield, vigour and reaction to major diseases. Ten of these top yielders are presented in Table 6. They are being grown as promising lines at Bukalasa Experimental Farm for possible advancement through the breeding sequence and future release. Furthermore, some entries have been pulled out of the collections to make Rust, CBB or halo blight nurseries.

Cooking Time and Moisture Absorption

Though consumers indicate that their preference for the varieties Kanyebwa, Kamplike and K 20 is based on their fast cooking time, this was not reflected in the results presented in Table 7. Variety K 130 had the fastest cooking time among the local varieties and variety Kanyankole the longest. The shortest cooking time was found in the introduction CATU.

The varieties tested had all been grown in the same season at the same location, thus ruling out any variation that could be attributed to these two factors. There is need to establish whether the cooking time results in the laboratory are compatible with times observed when the consumers' cooking methods are used.

Table 4. A Comparison of the Performance of Some CIAT Bean Introductions with Some Local Materials at Kawanda During the 1st and 2nd Seasons, 1984.

	Vigour		ALS		RUST		ANTHRACNOSE		BCMV		RAMULARIA		YIELD (KG/HA)		100 SEED WEIGHT	
Seasons	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
<u>Variety</u>																
A-83	4	3	1	2	1	2	1	1	1	2	2	3	1142	880	17.4	17.4
A-140	3	4	1	1	1	1	1	1	1	1	3	3	1344	877	17.2	16.3
A-153	4	3	1	2	1	1	1	1	1	1	3	4	884	858	16.9	17.1
A-162	3	3	3	3	3	3	1	1	1	3	3	3	1187	745	17.0	17.2
A-177	3	3	1	2	1	1	1	1	1	2	3	4	1186	1018	17.7	17.2
BAC-36	4	3	1	1	1	2	1	1	1	2	2	3	678	815	16.7	17.2
BAT 1220	3	3	2	2	2	3	1	1	1	1	2	2	968	674	16.8	17.2
BAT 1275	4	4	5	5	5	4	1	1	1	1	2	2	512	317	36.4	31.2
BAT 1276	4	4	5	5	5	4	1	1	1	1	2	2	454	271	36.8	31.0
CATU	3	3	2	3	2	3	1	1	1	1	2	2	1316	1008	17.8	17.0
Linea-24	4	4	5	5	5	5	1	1	1	1	2	2	511	322	36.9	31.8
CARIOCA 112	3	3	2	3	2	2	1	1	1	2	3	4	1186	1049	17.6	17.6
(Kanyebwa)	5	5	4	3	5	3	1	1	1	1	2	2	150	68	34.9	30.0
K 130	3	4	5	5	4	5	1	1	1	1	2	2	765	309	36.5	32.1
K 20	4	4	5	5	5	5	1	1	1	1	2	2	445	358	37.3	32.7
Kampulike	4	4	5	5	5	5	1	1	1	1	2	2	398	326	21.4	20.2

Scored Scale 1 = least, 5 = worst. LSD = 361 313

Table 5. Variation in Yield and Other Characters of Introduced Bean Varieties.

Variety	Vigour	Habit	CBB	Rust	Anthracnose	Mean yield (kg/ha)
Kanyebwa	3	1	4	4	1	694
Kampulike	3	2	3	2	1	1017
K 130	3	1	4	3	1	1063
K 20	3	1	4	4	1	1215
BAC 36	3	2	1	1	1	1750
A-83	3	2	2	1	1	1931
A-140	3	2	2	1	1	2194
CATU	3	2	3	2	1	2438
CARIOCA	2	2	2	1	1	2454
A-162	3	2	3	1	1	2639
BAT 1220	2	2	2	2	1	3243

For yield LSD 0.05 = 1.16, Plot size = 1.8 x 4 m

Table 6. Performance of Some 1984 VEF Introductions.

Variety	VIG	ALS	RUST	ANTH	CBB	Yield kg/ha
DOR 343	1	1	2		1	705
DOR 340	2	1	1		2	634
RIZ 32	3	1	2		1	604
DOR 339	2	1	1		1	590
RIZ 31	2	1	1		1	581
EMP 89	3	1	1		3	580
DOR 337	3	1	2		1	579
DOR 346	2	1	1		1	567
RIZ 34	2.5	1	1		3	558
EMP 146	3	1	1		1	556

Some varieties initially absorbed moisture rapidly and then slowed down while others were initially slow and the rate increased later. However, almost all ended up absorbing nearly the same amount apart from A-162 which absorbed very little comparatively. There was no relationship between cooking time and moisture imbibed. The quality observed in the fast cooking varieties may be related to the chemical composition of the seed other than hard testa and water absorption alone.

Table 7. Moisture Imbibition and Cooking Times.

	Imbibed Water ml/100g Seed, with Time (minutes)					
Variety	1	2	3	4	14	Cooking Time (minutes)
BAT 1220	58.09	62.55	79.37	83.48	91.66	137
A-162	39.69	42.27	53.07	56.25	63.30	99
KAMPULIKE	54.01	71.66	74.80	77.55	89.23	112
K 20	24.86	46.30	79.67	82.52	95.00	95
K 130	25.28	62.76	83.13	86.17	90.00	87
KANYEBWA	33.06	60.42	70.59	72.22	90.01	99
WHITE HARICOT	57.64	71.56	76.13	79.13	88.03	119
KANYANKOLE	32.55	57.09	66.00	77.56	92.28	175
KAINJA	25.43	54.67	67.82	83.38	90.50	114
NAMUNYE RED	54.52	65.90	80.76	84.77	91.80	131
MUTIKE RED	36.67	70.95	72.11	82.68	93.00	160
BAC 36	-	-	-	-	-	125
A-83	-	-	-	-	-	112
A-140	-	-	-	-	-	110
CATU	-	-	-	-	-	82
CARIOCA	-	-	-	-	-	125
BLack Haricot	-	-	-	-	-	142
Mottled Kainja	-	-	-	-	-	139
Lajja	-	-	-	-	-	175

Conclusion

On assembling the collections other cultivated species of phaseolus were not collected since they are of minor importance as a crop and the utilisable variation existent in *Phaseolus vulgaris* is considerable. Further experiments may be required on a yearly basis so as to keep track of the variation that is generated within the populations handled by the farmers across seasons. When multilocational testing of this material is accomplished, new varieties are likely to be released in the near future. The germplasm evaluation needs to be carried out at different locations so that the germplasm is exposed to all the possible variants within the bean pathogens and pests prevalent in the country. Consideration should also be given to including inoculations during germplasm evaluation.

There is need for more research directed at other production constraints such as poor soils or disease infested soils, storability, marketability, labour and availability of inputs. Besides lack of improved varieties, the farmers also indicated problems such as lack of nearby markets, no transport, lack of funds to purchase inputs and hire labour.

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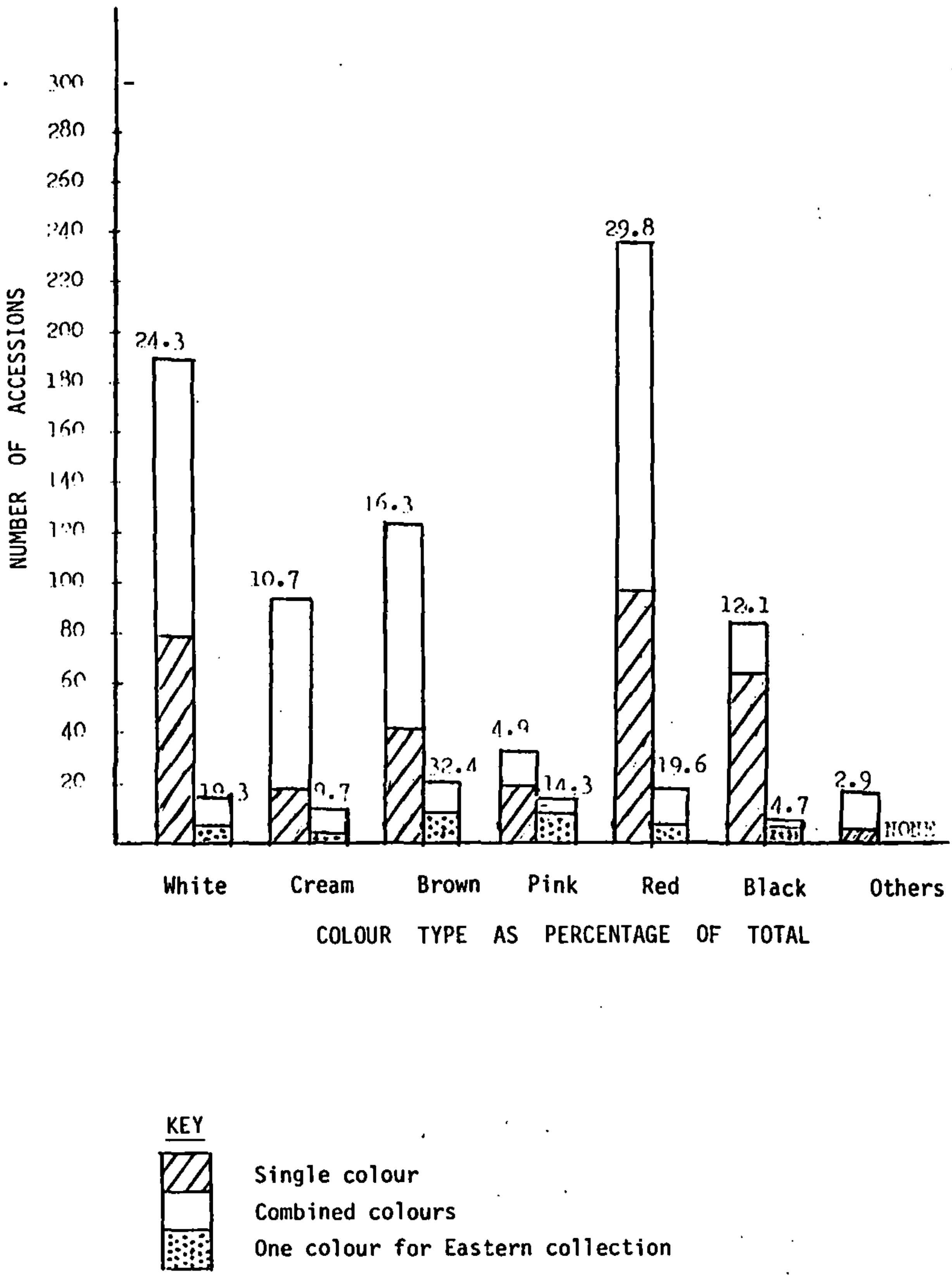
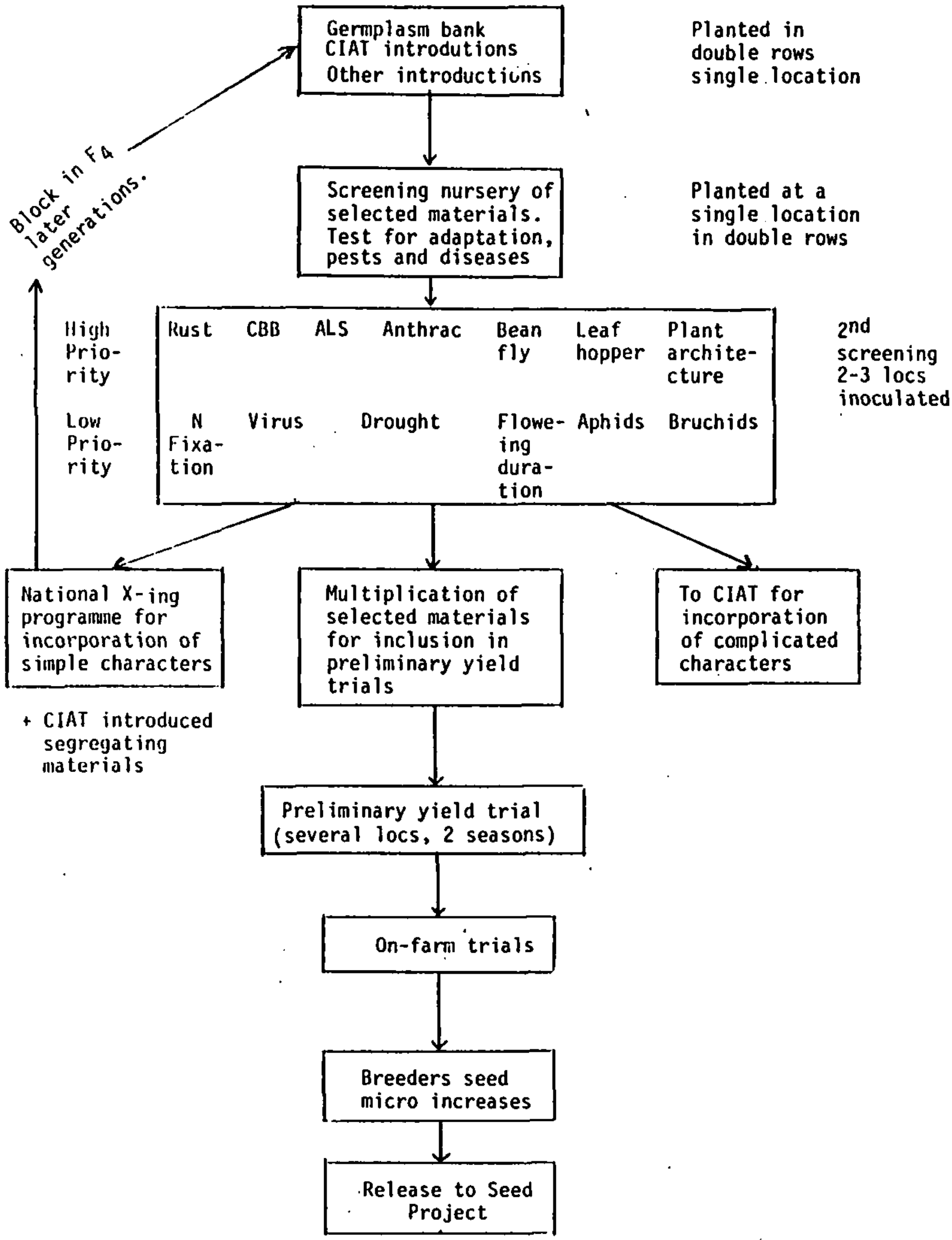


Figure 1. Variation in Seed Colours in the Kawanda Bean Germplasm (1986)

APPENDIX 1

STEPS IN EVALUATION OF BEAN LINES IN UGANDA



Adaptation and Resistance in Bean to Angular Leaf Spot and Rust in Kenya

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Introduction

Beans (*Phaseolus vulgaris L.*) are the most important grain legumes grown in Kenya, forming an important and relatively cheap source of dietary protein for a substantial part of the population. The crop is grown mainly in association with maize, bananas, pigeon peas, coffee, sorghum or vegetables although a relatively smaller area is grown in monoculture. Although yield levels range up to 2 to 3 tonnes/ha, the average yields are generally low (750 kg/ha in monocrop and 375 kg/ha in association with maize) (Njugunah *et al.*, 1981). Elsewhere, yields of up to 5 tons/ha (monoculture) and 2 tons/ha (in association with maize) have been obtained under experimental conditions (Roberts, 1970; CIAT, 1974; Francis *et al.*, 1977).

The low yields obtained are attributed to a number of constraints, most important of which are diseases and pests (Njugunah *et. al.*, 1981). Diseases of beans considered to be of major economic importance in Kenya include rust, angular leaf spot, anthracnose, halo blight, common bacterial blight and bean common mosaic virus (Hubbelling, 1973; Mukunya and Keya, 1975; Njugunah *et al.*, 1981). Importance and severity of these diseases vary from one season to another and from one ecological condition to another.

Standard practices recommended for the control of bean diseases include use of cultural and/or chemical methods. These methods are limited, however, when practised by small-scale farmers who have limited resources and technology. Development and introduction of multiple disease resistance bean cultivars combined with other disease control practices offers an effective and relatively cheap means of reducing yield losses. This, however, entails development in local popular cultivars of desirable agronomical and disease-resistant characteristics by utilising both local and introduced bean germplasm. This paper reports preliminary results on yield performances and on disease reaction to rust and angular leaf spot of a number of introduced bean accessions.

Materials and Methods

To determine yield performance and reaction to artificial infection of rust and angular leaf spot, two field experiments were carried out during the long and short rain seasons of 1985 and 1986 respectively, at the field station of the Faculty of Agriculture, University of Nairobi. Of the 55 bean accessions used in the study, 50 were promising lines from Centro International de Agriculture Tropica (CIAT), Cali, Colombia and five were from the University of Puerto Rico (United States Department of Agriculture). Four local varieties were used for comparison.

Each line and/or cultivar was planted in five row plots measuring 3 metres long with a spacing of 75 cm between the rows and 15 cm within rows. A complete randomised block design with three replications per treatment (variety) was used. No fertiliser application was made, but other normal cultural practices were carried out. Two seeds to a hill were planted but later were thinned to one after germination giving a near perfect plant population of 110 plant/ha. At harvest three centre rows were harvested, threshed, sun-dried and used to determine grain yield.

Disease Rating

Disease reactions of cultivars were based on artificial infection, and severity was estimated on 25 randomly chosen plants per plot. Severity rating for angular leaf spot was based on a CIAT evaluation scale of 1 to 5 (CIAT, 1978) representing varying percentage of actual leaflet area covered with lesions where 1 = no apparent symptoms, 2 = less than 2% of actual leaflet area covered with lesions, 3 = 3-10% of a leaflet area covered with lesions, 4 = 11-25% of leaflet area covered with lesions often accompanied with chlorosis, 5 = worse than 25%.

Disease severity rating for rust was estimated using the scale of Crispin and Dongo (1962) where infection types 0=immune, no symptoms, 1=small chlorotic lesions, no pustules; 2=numerous small pustules barely on lower leaf surface; 4=many pustules on upper and lower leaf surface, 5 = numerous large pustules on upper and lower leaf surface, leaf margins may be dead and entire leaf may be chlorotic.

Results

Yield Performance

There were highly significant differences for yield among the bean lines tested during both seasons. Yields varied between 304-4348 kg/ha with an average of 2572 kg/ha and 264-2970 kg/ha with an average of 1519 kg/ha during the long rain season (1985) and short rain season (1986) respectively (Tables 1,2).

Table 1. Mean Yields (kg/ha) of the Local and Introduced Bean Lines During the Long Rain Season (1985) and the Short Rain Season (1986).

Origin	Line/cultivar	Mean yield kg/ha	
		Long rain season (1985)	Short rain season (1986)
Local	Red haricot (NB86)	2876	1586
	Mwezi Moja (NB518)	2274	1661
	GLP2 (NB510)	2313	1638
	Small Rose Coco (NB1122)	2236	1122
Puerto Rico	4M - 49	3977	1726
	L - 227 - 1	3060	2152
	3M - 150	2092	1053
	L - 226 - 10	3265	1229
	3M - 152	2359	1596
CIAT	A476	4353	2644
	BAT 1582	3053	2429
	BAT 332	2490	1483
	A 156	1021	804
	BAT 1617	637	613
	A - 82	-	-
	A - 140	1881	1649
	A - 155	3079	2623
	A - 166	-	-
	A - 163	2758	1247
	A - 171	2757	2269
	A - 176	1906	1578
	A - 187	1583	1115
	APN 18	2613	1592
	BAC 57	4331	2179
	BAC 68	3798	2452
	BAT 44	3601	1678
	BAT 841	3418	1289
	BAT 1211	1048	561
	BAT 1252	2484	650
	BAT 1266	1772	1698
	CENA 163 - 1 - 1	3016	1840
	OJO DE ORO	2988	1273
	GO 2402	2753	1184
	TOCHE 400	2922	1382
	VO 7917	1209	1102
	VO 7919	1842	1226
	VO 7987	1762	941
	VO 8020	2296	1893
	BAT 76	2383	665
	G 2858	2554	1361
	CORBEL 49-242	-	-
	A - 476	2001	2693
	A - 482	3205	2970
	A - 484	3728	1918
	A - 485	1997	732
	BAT 1386	1264	1286
	BAT 1426	4348	1443
	BAT 1427	1730	1361
	BAT 1430	3646	1866
	BAT 1580	2185	1324
	BAT 1583	3060	1246
	BAT 1618	3218	2407
	BAT 1620	2753	1678
	BAC 122	3379	1892
	BAT 1667	2821	2025
	A 475	3241	1567
	A 478	2266	1055
	BAT 1385	-	-
Mean		2572.3	1519.4
Range		304 - 4348	267 - 2970
LSD 5%		79.46	78.36
LSD 1%		104.43	102.98

Table 2. Mean Squares for Grain Yield (Kg/ha) of Bean Lines During the Long Rain Season (1985) and Short Rain Season (1986).

Source	df	MEAN SQUARE Long rain season (1985)	 Short rain season (1986)
Block	1	12695.8**	12337.6**
Varities	55	11378.3**	11149.4**
Error	55	1643.7	1598.9

* , ** Significant at 5% and 1% probability levels respectively.

With respect to yield, the lines gave normal distributions in both seasons. However, during the long rains (1985) the bean lines showed more variation and spread from the mean than during the short rains (1986), implying that the former environmental conditions enabled cultivars to express their potential which was otherwise masked in the latter conditions (Fig. 1).

Disease Reactions

The main diseases recorded during both seasons were angular leaf spot and rust. However, low incidences of anthracnose were noted during the long rains (1985). Disease severity of angular leaf spot and rust was on average higher during the long rain season (1985) than in the short rain season (1986). Cultivars A156, BAT 1617 and A478 from CIAT gave very susceptible reactions to rust. Occurrence of the disease was early, resulting in numerous and large pustules and chlorosis of leaves. Consequently, the yields of these cultivars were very low. On the other hand, about 2/3 of the tested lines gave resistance reactions (Table 3). The latter ranged from immune to low infection types. The local cultivars, small Rosecoco (NB 1122) and Red Haricot (BN 86), were similarly resistant. Out of 43 CIAT entries evaluated for disease resistance to angular leaf spot, 28 gave a resistant reaction, eleven gave intermediate and four were susceptible (Table 4). Of the five lines from Puerto Rico, three were resistant whereas two were intermediate in reaction. Among the local lines, Mwezi Moja (NB 518) was susceptible while GLP2 (NB510) and small Rosecoco (NB 1122) gave intermediate reactions.

Discussion

Bean lines tested during the two rain seasons showed significant variation both in their yield and disease reaction. This may have been due to their differences in genetic potential

Table 3. Origin of Bean Lines and Their Disease Reaction to Inoculation with Rust During the Long Rains (1985) and the Short Rains (1986) Seasons.

	ORIGIN OF BEAN LINES				
Disease Reaction	C I A T			Puerto Rico	Local
0 - 2.5	A155	BAT 1211	Michigan Red Kidney	L 226-10	Small Rose Coco (NB1122)
	A163	BAT 1252	A482	L 227-1	Red Haricot (NB86)
	A176	BAT 1266	A484	4M-49	
	A187	CENA 163-1-1	BAT 1384		
	APN 18	OJO DE ORO	BAT 1426		
	BAC 57	TCCHE 400	BAT 1427		
	BAT 841	BAT 332	BAT 1580		
	BAC 122	A 476	VO 7987		
	A464	BAT 1618	BAT 1620		
	A485				
2.6 - 3.5	BAT 44	VO 2402	VO 7917	3M - 150	Mwezi Moja (NB518)
	VO 8020	BAT 76	G 2858	3M - 152	GLP2
	BAT 1430	BAT 1667			
3.6 - 5.0	A156 (VS)	BAT 1617 (VS)			
	A1715	A478 (VS)			
	BAC 68 (VS)				

Table 4. Origin of Bean Lines and Their Disease Reaction to Inoculation with *Isariopsis griseola* During the Long Rains (1985) and the Short Rains (1986) Seasons.

Disease Reaction	ORIGIN OF BEAN LINES				
	CIAT			Puerto Rico	Local
1 - 2.5	A156	BAC 68	G2858	L 226 - 10	Red Haricot (NB 86)
	A163	BAT 44	A 464	L 227 - 1	
	A171	BAT 1266	A 476	AN - 49	
	A176	VO 7919	A 482		
	A187	VO 7987	A 485		
	APN 18	BAT 332	BAT 1356		
	BAC 57	BAT 76	BAT 1426		
	BAT 1427	BAT 1583	BAT 1617		
	BAT 1618	BAT 1628	BAC 122		
	A 476				
2.6 - 3.5	A 155	BAT 841	CENA 163-1-1	3M - 150	GLP 2
	GO 2402	TCCHE 400	VO 7917	3M - 152	Small Rose Coco (NB 1122)
	VO 8020	BAT 1430	BAT 1580		
	BAT 1667	A 478			
3.6 - 5.0	BAT 1211	BAT 1252	OJO DE ORO		Mwezi Moja (NB 518)
	MICHIGAN DARK RED KIDNEY BEAN				

and influences of environment on some of them. Environmental condition was apparent on yield and disease during the two growing seasons. High rainfall (316.8 mm) during the long rain season resulted in higher yields of disease-resistant cultivars than during the short rain reason (171.3 mm). This implied that the introduced cultivars are likely to react differently to the varied agro-ecological conditions where beans are grown in Kenya. Their suitability and potential in these areas need to be determined before appropriate recommendations can be made.

Data obtained in this study also showed possible variation in genetic factors governing resistance and susceptibility to angular leaf spot and rust. Since pathogenic variations exist in both rust and angular leaf spot (Buruchara, 1985), reactions observed in this study may not necessarily be the same depending on the existing pathogenic variability of the pathogen.

One of the ways of increasing production of bean yield in Kenya is through genetic improvement of existing popular bean cultivars. Data obtained in the present study show that a good number of introduced bean lines have inherent good yield potential and resistance which may be exploited in improving the yields of local cultivars. However, more research is necessary and should consider the varied growth habits, cropping practices by small farmers and seed colour preferences before appropriate recommendations are made to improve production of local cultivars.

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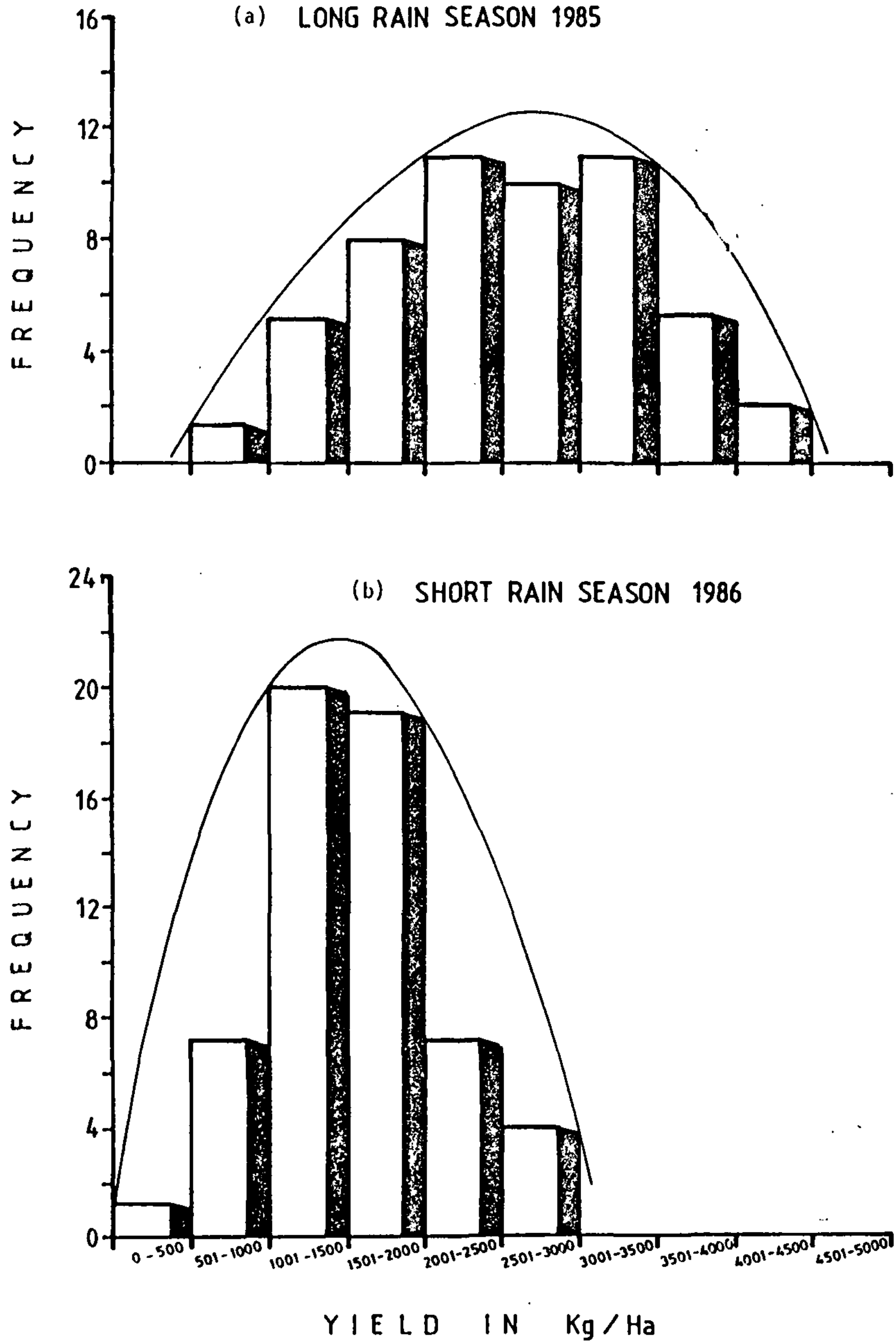

Figure 1. Frequency Distribution of Grain Yields for Bean Lines grown in Short and Long Rain Seasons with Disease Inoculations.

SUMMARY OF DISCUSSION

Observation of disease incidence on varieties in non-inoculated field trials are useful, but inoculation may be necessary to ensure good, uniform pressure for selecting resistant parental lines.

Multiplication of basic seed of new varieties poses a problem in several countries. Antibiotics are needed in some cases to reduce CBB infection, and seed should be packaged in convenient units for small farmers, say 5 kg (otherwise, larger packets tend to be bought by market traders and opened for retailing in smaller amounts).

No conflict of interest should occur between the seed producer and a breeder who aims to retain genetic variability in a released variety. In a self-pollinated crop, variability for wide adaptation can be obtained by developing a multiline, the components of which can be multiplied separately.

35648

SESSION IV : CROP PROTECTION

Research on Common Bean Diseases in Ethiopia: A Review

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Introduction

Common beans play an important role in the cropping systems and nutrition of the Ethiopian farmers. Beans are grown in Ethiopia as relay crops with cereals. The average yields of beans obtained by the farmer are extremely low, ranging between 600-800 kilogram per hectare. These low yields may be attributed to a combination of several yield constraints among which diseases play a major role (Ohlander, 1976, 1980). Its wide adaptation exposes the bean plants to a number of diseases. The success of a bean improvement programme depends partly on the identification, recognition and control of these diseases.

Before the establishment of a nationally co-ordinated programme on pulses in 1972, little attention was given to food legume diseases in general and to common beans in particular. Since then, however, a need was felt to strengthen the pathological aspect of the common bean improvement programme.

This report provides the present status of knowledge in bean pathology and tries to identify high priority areas of research for the future. A brief review is given on the general disease survey followed by a discussion on the control of major bean diseases such as bean rust, anthracnose, common bacterial blight, other foliar diseases and nematodes.

General Disease Surveys

Extensive surveys of bean diseases have been made throughout the country, and nearly 200 mycological specimens have been collected and preserved at Holetta and Nazret research centers. Most of the pathogens associated with these diseases have been identified and documented. A list of food legume diseases recorded in Ethiopia is give in Table 1. .pa

Foliar Diseases

Stewart and Dagnatchew (1967) listed more than twelve fungal

Table 1. Common Bean Diseases Reported in Ethiopia

Common Name	Causal agent	Status	Source (ref.)
bean rust	*Uromyces phaseoli*	major	Stewart and Dagnatchew (1967)
common bacterial blight	*Xanthomonas campastris pv. phaseoli*	"	
bean anthracnose	*Colletotrichum lindemuthianum*	"	
angular leafspot	*Isariopsis griseola*	"	
flowery leafspot	*Mycovellosiela phaseoli*	intermediate	
halo blight	*Pseudomonas synigae pv. phaseolicola*	"	
root-knot nematode	*Meloidogyne incojnita*	"	
root rot	*Sclerotium rolfsii*	"	
leafspot	*Ascochyta phaseolorum*	minor	
leafspot	*Cercospora cruenta*	"	
stem anthracnose	*Colletotrichum truncatum*	"	
leafspot	*Phyllosticta phaseolina*	"	
leafspot	*Phoma exigua*	intermediate	Awgechew (1982)
leafspot	*P. phaseolina*	?	
leafspot	*Mycospharella pinodes*	minor	
leafspot	*Cercosporidium spp.*	"	
leafspot	*Periconia byssoides*	"	
mosaic virus	BCMV	intermediate	Agranovsky, Bos
wilt	*Fusarium oxysporum*	"	unpublished
stem rot	*Sclerotinia sclerotiorum*	minor	"
ashy stem blight	*Macrophomina phaseoli*	"	"

and bacterial foliar diseases affecting food legumes in Ethiopia. Recently, however, this list has increased to seventeen as reported by Awgechew (1982). Currently the figure is higher than both estimates since there are other diseases unreported by both authors but indicated in other publications.

Of these reported diseases, bean rust, phoma (ascochyta) blight, common bacterial blight and bean anthracnose have a much wider distribution. Angular, flowery and ascochyta leaf spot are limited to certain regions where there is high rainfall and temperature.

Viral Diseases

The viral diseases of beans have received less attention than any of the other diseases. Active work on legume viral diseases rests on survey and identification, and most reports reveal only visual assessments which are subject to further confirmation.

The effect of viruses can be destructive as has been observed in some areas. Stewart and Dagnatchew (1967) were the first to mention the occurrence of plant viruses in Ethiopia. They listed mosaics in haricot bean without mentioning their virus cause.

Barat (1968) and Delassus (1972) mentioned the occurrence of virus symptoms in haricot beans. Bos (1974) described a mosaic disease of haricot bean in the lowlands and rift valley regions of Ethiopia. He suggested the virus to be the seed- and aphid-transmitted bean common mosaic virus (BCMV) which could be found nearly everywhere. Incidences up of to 90% were especially common in the lower altitudes and 5 to 25% in most other areas. Agranovsky (1985) confirmed the presence of BCMV or its strain from samples collected at Melkassa, Awassa and Ambo. BCMV incidence is higher in the lowlands probably due to higher aphid population in the region.

Nematodes

Root-knot nematodes are becoming more important as the cultivation of fields become more intensive. O'Bannon (1975) mentioned that the root-knot nematode, *Meloidogyne* spp, were the most dominant nematodes found associated with nearly 40% of the legume samples. He listed four different genera, but did not indicate the genus *Meloidogyne* in harioct bean. Later, severe incidence of root-knot nematode was reported from Melkassa, Bako and Didessa (Table 3).

Table 1. Distribution and Severity of Bean Diseases

DISEASES	AMBO	AWASSA	BAKO	BIRR	DEBRE ZEIT	JIMMA	KOBO	METU	NAZRET	DIDESA
Bean rust	+++	+++	+	+	+	+++	+		+	+
Anthracnose	++	+++	++			+++		++	+	+++
Phoma blight	++	++	+++	+	++	++	++	+	+++	++
Ascochyta leafspot			++			+		++		+
Floury LS		++	+++			+++		+++		+
Angular LS		++	+			++		+++		+
Sclerotinia sclerotiorum		+				+				
Alternaria sp.		+								
Macrophomina sp.				++	+					
Sclerotium rolfsii		+	+		+				+	
Fusarium spp	++	+	+		+			+	+	
Rhizoctonia sp.		+	+		+			+	+	
CBB	+	++	+		++	+			++	+
HB	++	++	+		+				++	
BCMV	++	+++							+++	
ROOT KNOT NEMATODE			++						++	++

Table 3. Nematode Incidence in Haricot Bean in Ethiopia

Nematode genera	Location	Relative abundance
Helicotylenchus	Jimma	Very few
Pratylenchus	Jimma	Very few
Rotylenchulus	Jimma	Few
Tylenchorhynchus	Jimma	Very few
Meloidogyne	Melkassa, Bako, Didessa	Numerous

Control Measures

Bean Rust

Bean rust (BR) caused by *Uromyces phaseoli* has a wide geographical distribution in Ethiopia. Although it can infect many species of Phaseolus it has been particularly damaging to haricot bean in this country. It causes one of the most important production problems in areas such as Awassa, Jimma and Bako. In some years it can wipe out susceptible varieties (Table 4). Varieties Tara, Nazert Small and Pinto Bean gave no yield at Awassa but were among the highest yielders at Melka Werer where the climate is dry, irrigation was practised and no bean rust was reported.

Cultural Control Studies

Cultural control recommendations include crop rotation, removal of plant debris, sowing dates and plant population densities. No attempt was made to study the effect of these practices in a detailed manner. Adjusting planting dates was reported to influence the incidence of rust infection in haricot bean. In a sowing date trial at Bako, of the three sowing dates (May, June, July) tested on the variety Sanilack the July sowing was reported to develop a 60% rust attack (IAR, 1972; IRAT, 1971). This has not been confirmed in subsequent years, and the

Table 4. The Effect of Bean Rust on the Yield of Some Haricot Bean Varieties at Awassa and Melka Werer, 1974.

	Awassa			Melka Werer		
Entries	Rust (0-5)	Yield (q/ha)	Rank	Rust (0-5)	Yield (q/ha)	Rank
Black Dessie	1.0	29.3	1	0.0	29.3	11
Brown Speckled	2.0	19.6	2	0.0	36.5	4
Mexican 142	4.0	7.2	3	0.0	33.3	9
NS 203	5.0	3.3	4	0.0	39.2	2
6R395	5.0	1.8	5	0.0	35.3	6
Jules	5.0	0.0	-	0.0	32.7	10
Emerson	5.0	0.0	-	0.0	34.6	7
Pinto Bean	5.0	0.0	-	0.0	35.5	5
Nazret Small	5.0	0.0	-	0.0	34.3	8
WS84	5.0	0.0	-	0.0	38.4	3
Tara	5.0	0.0	-	0.0	42.3	1

(After IAR, 1977)

result is likely to change depending on the weather conditions. At Awassa (*IRAT, 1970*) regardless of sowing dates, all bean crops were more or less attacked by rust. If rain continues in October and November the late-sown ones can be equally affected. But it generally proved that bean rust reduces yields more severely when infection occurs before flowering than when it occurs after flowering (Schwartz and Galvez, 1980).

Host Resistance

Many reports on identification of resistance to BR appeared in the literature during the last fifteen years (IAR, 1972, 1973, 1975, 1977; IRAT, 1971). Many of the reports were based on observations made during natural epidemics. No attempt was made to confirm such claims based on artificial inoculation trials in the field or in the greenhouse.

There are strong indications, however, that one of the main causes of yield variation between varieties was the difference in disease resistance (IAR, 1972; IRAT, 1971; Ohlander, 1980). IRAT (1971) conducted a selection programme on the variety Satin P with the aim of obtaining, among other things, a difference in susceptibility to rust disease. In the fourteen selections made, the rust reaction ranged from 0-5 in a 5-point scale, in one season cycle. Nine out of the fourteen selections gave a score of 3 and above. In the 1973 national yield trial it was reported that the varieties Ethiopia 10, Mexican 142 and Tengeru 16 were partially resistant while Nazret Small, Seaway and Gratitiot were completely susceptible. In a similar trial in 1974 there was a severe incidence of BR throughout the experimental sites. The local variety Black Dessie had shown the lowest disease score and the highest yield on the average. On the other hand, the variety Tara, which was heavily infected by BR, gave the lowest yield.

Since then, Black Dessie and, in latter years, Negro Mecentral consistently showed less rust and high yields whereas varieties such as *Mexican* 142, Tara, Jules, Nazret Small, Gloria, Tengeru 16, Nazret Selections 178 and 148, clearly showed susceptible reactions. This was particularly evident in the 1982 and 1983 rust screening trial conducted at Ambo, Awassa and Jimma. Of the 206 entries evaluated at these locations, 28 entries were rust-free. These entries were checked again in 1984 at Ambo and showed similar results; these include W62, W73, W117, 7BRN42-2, M103, Negro Mecentral and Epid Sample 30. None of these entries, however, was released to farmers. Very recently attempts were made to start a breeding programme to incorporate these resistant genes into those varieties which are susceptible but have a high demand both by consumers and international markets.

Chemical Control Trials

Chemicals such as sulfur, chlorothalonil, maneb or mancozeb have been recommended as preventives in the literature, and attempts were therefore made to prove the claims under Ethiopian conditions. Similar chemicals and others were tested at Bako (IAR, 1975) to control bean rust. Oxycarboxin and captafol were reported to be effective against BR.

Bean Anthracnose

Anthracnose is a common disease in areas such as Awassa, Arsi Negellie, Kulumsa, Bako, Didessa and Ambo. It is found less often at Nazret, Debre Zeit and Jimma. Because of its attack on pods, the quality of seeds as well as the seed yield is greatly reduced. No figure is available on the extent of loss due to the disease, and evaluation made on the various variety trials fail to show any significant relation between disease incidence and yield. But it is felt that under severe conditions and if a susceptible cultivar is planted, the loss could be substantial.

Varietal Resistance

Early in the implementation of the pulse improvement programme it was reported that some varieties differ in their reaction to anthracnose. Hence, a disease screening nursery was conducted for two successive years in 1974 and 1975 (IAR, 1977). A total of 71 lines were screened at Bako and Kulumsa. At Bako, 24 of the 71 entries included in the trial gave a mean score of 1 or less in a five-point scale. Over all, the entries Red Wolaita and Negro Mecentral gave the lowest disease score and the highest yield. Entries such as Pinto Bean, Emerson, Jules, W117, W95-08, M103,15R57, W73 and the peabean types were susceptible.

The screening trial was conducted under natural epidemics and the infection was not absolutely uniform throughout the experiment plot.

Chemical Control Trials

Various chemical treatments have been examined as a control of bean anthracnose at Bako and Nazret. Seed infections (Habtu and Awgechew, 1984; IAR, 1973) were controlled by captafol treatments. The pathogen is able to survive both in the seed and on the seed coat. It is much easier to accomplish seed coat eradication than those in the internal seed contaminations. Systematic fungicides may need to be attempted in any future programmes.

Spraying protectant fungicides has been attempted by Holetta plant pathology laboratory in cooperation with Nazret (Habtu and Awgechew, 1984). Five fungicides were included and it has been possible to increase yield by 53% and 89% with the two most effective fungicides (Table 5). Seed treatments followed by spraying may prove more effective especially when the need arises to produce disease-free seed.

Table 5. The Effects of Fungicide Treatments on the Anthracnose Disease Intensity and Yield of Haricot Bean.

Treatments	Diseases score 0-3	Yield (q/ha)	In % of control
Unsprayed check	1.6	22.5	100
Benomyl (0.03%)	0.6	27.2	121
Metagram (0.02%)	1.2	21.4	95
Captafol (0.02%)	0.1	42.6	189
Mancozeb (0.025%)	0.6	34.5	153
Copperoxychloride (0.50)	1.2	24.5	109

(Source: Habtu and Awgechew)

Bacterial Blights (BB)

Two kinds of bacterial diseases have been reported in Ethiopia (Ohlander, 1980; Stewart and Dagnatchew, 1967). These are common bacterial blight (CBB) caused by *Xanthomonas campestris* pv *phaseoli* and halo blight (HB) caused by *Pseudomonas syringe* pv *phaseolicola*.

In the early 1970s, when the pulse improvement programme was initiated, CBB and HB were reported to be widely distributed in almost all major bean growing regions (IAR, 1985; IRAT, 1971).

They seemed to occur regularly and frequently in several locations, Ohlander (1976) attributed a yield variation from year to year due to CBB. In the 1985 and 1986 cropping season a high incidence of HB was observed in haricot bean.

Cultural Control Practices

Cultural practices often studied to reduce BB include the use of pathogen-free seed, proper crop rotation, deep plowing, sowing dates, population densities and weeding practices. Effects of plant densitities and weeding practices were found to have a limited effect on the spread of the HB disease in Melkassa fields under conditions where the temperature is high and humidity is normally low (Habtu Assefa, unpublished).

HB seems to prefer high plant densities for easy spread from diseased to healthy plants, but the effect on yield was not significant enough to warrant any shift away from the current practices. But, in areas where the temperature and humidity are high, the disease is expected to be high, and indications are that plants should be spaced as widely as possible. The best alternative is the use of disease-free seed and if possible proper crop rotation with unrelated crops, wherever possible.

Varietal Resistance

Bean cultivars are known to vary in their reaction to infection by BB. The variation appears to be much greater for HB than CBB. As far as CBB is concerned, none of the lines that have been studied since the early 1970s indicate freedom from infection, but there is a degree of variability (IAR,1975, 1977). In the 1974 cultivar screening trial, 49 entries were evaluated of which Negro Mecentral and W95 seemed to show less blight incidence while 6R395, Jules, Tara, 6R390 and Nazret Selection 27 were extremely susceptible (IAR, 1977). In 1975, of the 71 entries tested at Debre Zeit none was rated below one in a 5-point scale and at Bako in a relatively slight blight incidence year, 36 of the 71 entries were rated less than one. In the 1986 nursery BAC 38, 6R-395-08, W117, Negro Mecentral and BAC 87 were found resistant.

As far as HB is concerned, entries Velasko and Brown Speckled were extremely susceptible while most entries appeared to be resistant. But, these observations were merely visual and subjective based on natural infections. There is no doubt that there is room for improvement in testing bean varieties either under natural or controlled conditions to eliminate or reduce the chance of escape.

Chemical Control Trials

Various chemicals were tested both as seed treatment or foliage sprays to control mainly CBB at Melkassa conditions in 1981 and 1982 (Habtu Assefa, unpublished). Seed treatments with sodium hypochlorate, streptomycin, copperhydroxide and copper ammonium carbonate were tested in 1981 to determine their effect on seed infection but none of them appeared to be effective. There seemed to be a reduction of seedling infection, but as the plants grew older and because of transmission by wind and splashing rain, the disease spread faster to all, even the treated plots.

Foliar protectant chemicals such as copperoxychloride, copper ammonium carbonate, streptomycin and kasugamycin did not appear to be effective either. This appears to be in contrast to other studies (Schwartz and Galvez, 1980) where copper-based fungicides and antibiotics gave marginal control in the absence of any yield increment. In any case, antibiotics are not viable alternatives since resistant bacterial mutants can easily be developed. Copper-based fungicides may be effective when applied before the disease reaches an epidemic level.

Other Foliar Diseases

Common beans are exposed to many pathogenic fungi at various stages of their development, and common infections occur on natural plants. Some of the more prevalent foliar diseases include angular leaf spot caused by *Isariopsis griesola*, flowery leaf spot caused by *Mycovellosiella phaseoli* and blight (*Phoma* spp).

Of these, phoma blight is the most dominant and widely distributed pathogen. It is now spreading to almost all bean growing regions. There was little report of this disease in the 1970s. In his complete summary of research in haricot beans in Ethiopia, Westphal (1974) has not mentioned the presence of phoma blight. Now, however, one cannot overlook the presence of this disease in most bean-growing locations.

Phoma blight is the most common disease at Melkassa, Awassa, Bako, Jimma and Kobo. There seems to be less varietal variability than bean rust where immune or resistant varieties are obtained. Severe epidemic causes premature defoliation, but yield losses have not been quantified yet.

Angular leaf spot of beans is prevalent in high rainfall, humid regions of the country such as Jimma and Metu. It is also present at Awassa and Bako. The fungus is known to have a wide host range (Schwartz and Galvez, 1980) but the disease is now reported from common beans in Ethiopia.

Varietal difference has been clearly seen in common beans (Table 6) but no attempts have been made to systematically screen varieties against this disease. Even though the disease is restricted in distribution to only certain regions, it will be very difficult to produce haricot beans at areas like Jimma unless efforts are made now to promote a well-planned programme on the study of the biology of the fungus and its control.

Flowery leaf spot has been reported to occur at Bako, Jimma and Metu areas and slight incidences were also reported from Awassa (IAR, 1985).

Research has not been conducted on the control aspect. Now it is considered a minor problem, at least in the major dry bean-growing regions.

Nematodes

Numerous nematodes are reported to be present associated with commom beans. Only a few of these exist in Ethiopia (O'Bannon, 1975), with species of *Meloidogyne* frequently occurring. Root-knot nematode is by far the most prevalent, and damaging, disease being reported from areas such as Melkassa, Bako and Didessa. Research on root-knot nematodes has not been extensive. Host-range and fumigation studies were the only research activities carried out once at Melkassa.

Host Range Studies

Twenty species of crops including haricot bean, lentils, chickpea, grass pea, mung bean and lima bean were evaluated for determining the presence of root-knot nematodes in their roots (IAR, 1977). The results clearly indicated that, of the 20 species tested, lentils, chickpea, grass pea, mung bean and lima bean were the most infected while pigeon pea, sweet potato and onion were the least infected plants. Haricot bean was intermediate.

Soil Fumigation Trials

In the soil fumigation trial to control root-knot nematodes, four species of legumes: Haricot bean, lima bean, mung bean, and adzuki bean were tested using two nematicides (IAR, 1977). Although there was no complete control of the nematode, dichloroporpane-dichloroporpene decreased the nematode infection significantly.

Basamid showed no significant effect except in mungbeans. Because of high incidence of root-rots in haricot beans it has not been possible to evaluate the treatment effects.

The trial was conducted during the dry season and the infection was actually moderate. The experiment was conducted only once under irrigation.

Table 6. Degree of Resistance in 35 Haricot Bean Entries to Phoma Blight and Angular Leaf Spot at Jimma, 1982 and 1983.

	1982 (0-5)		1983 (0-5)	
Entries	Phoma blight	Angular leaf spot	Phoma blight	Angular leaf spot
Black Dessie	2.67	2.50	2.0	2.7
Mexican 142	2.00	0.67	2.0	0.7
6R-395-08	2.67	0.00	2.0	0.3
FF-00017-35-F5	2.67	1.00	2.3	1.3
FF-00016-54-F5	3.33	0.33	2.0	0.3
M64 (21274-2)5-81	3.00	3.00	2.7	2.3
W95 (01)	2.00	1.00	2.0	0.7
EPID Sample 30	4.00	1.00	3.0	3.0
EPID Sample 10	2.00	1.00	2.3	1.3
Nazret Small-03	2.00	1.00	2.0	1.0
Ethiopia 10-39	2.67	1.33	2.3	2.0
W85 (21305-9)	0.00	5.00	2.0	4.2
IBRN 42-2	3.67	1.33	1.7	1.0
Acc. No. 313421	3.00	3.75	1.7	4.0
ICA Linea 34	2.67	2.75	2.0	2.3
B129 (21155-1)	3.00	0.33	1.7	3.0
B253 (20306-1)	3.33	0.67	2.0	2.0
B433 (0139-1)	2.33	0.67	1.2	2.0
EPID Sample 5	2.00	0.67	2.3	0.7
B123 (20393-1)	3.33	2.00	2.3	2.7
Ethiopia 10-40	2.67	2.00	2.0	1.7
Ethiopia 10-04	2.33	2.33	2.3	2.3
Ethiopia 10-27	3.00	3.00	3.3	3.0
W95-07	3.00	1.75	2.7	1.7
Tengeru 16-01	2.00	1.00	2.0	1.7
W95-02	2.67	3.00	2.0	2.3
Negro Mecentral04	2.33	0.67	2.0	0.0
B364 (7441-92)	3.33	1.00	1.3	2.3
15R57	3.00	1.33	1.7	3.0
M103 (20252-1)	3.00	1.33	1.3	1.7
15R-52	3.33	1.67	2.0	2.7
B933 (7641-254)	2.67	0.00	1.3	1.0
W117 (0150-1)	3.33	1.00	1.7	2.0
W132 (20711-1)	4.00	2.75	2.7	3.0
Mean	2.68	1.62	2.10	2.00
LSD 0.05	0.90	1.16	0.74	1.24
CV%	0.5	43.8	21.8	38

(After Habtu Assefa, unpub.)

Root Rots and Wilts

The fungus genera *Fusarium*, *Sclerotium*, *Marcrophomina* and *Rhizonctonia* were found to be the cause of the complex root rot and wilt diseases of commom beans. To alleviate the problem associated with such diseases a seed dressing trial was conducted at the experimental fields of IAR (1973). Despite a high incidence of four rots (80%), differences between treatment mean yields were very slight. Effects on either initial or mature plant stand was not reported.

Research Priorities

Common beans are attacked by a number of foliar diseases, viruses, root rots, wilts and nematodes. Now that the pathogens involved and the distribution of foliar diseases is understood, more practical and effective control measures have to be developed. Within the regional network, Ethiopia is now giving increased attention to all aspects of bean rust, while anticipating benefits from other countries in other research areas.

Fungicides may be screened against foliar diseases, but it is unlikely that they will be used on a large scale as the cost will be inhibitory to wide usage. It is necessary to strengthen the breeding programme to identify varieties that possess resistance to the foliar diseases and use them to combine with high yield.

Viruses, especially BCMV, can be important in beans. Information is lacking in their importance and distribution, thus, no practical and effective measure can be initiated. Beans are also susceptible to root rot and wilts. It will be rather unlkely to develop any one control measure against these diseases. An integrated control measure that includes proper measurement of soil cultivation, irrigation and drainage patterns, and crop rotation must be carried out. Resistant varieties have to be developed against these extremely plurivorous organisms.

Root-knot nematodes can become more serious as the cultivation of fields become more intensive. Research has to be directed towards the determination of economic damage to beans, host-range, appropriate pest management practices to reduce the nematode build-up and towards the development of resistant varieties.

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The Common Bean as a Symptomless Carrier of Pseudomonas solanacearum E.F. Smith

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Abstract

Seven varieties of beans (*Phaseolus vulgaris* L.) were tested for their reaction to *Pseudomonas solanacearum* E.F. Smith, under shade conditions at Kawanda (Uganda) in 1982 and 1983. All the bean varieties did not show symptoms of bacterial wilt but the bacteria (*P. solanacearum*) was isolated from all the bean varieties. The isolated bacteria caused 90-100% wilting when it was inoculated in tomato (*Lycopersicon esculentum* L.). This meant then that the bean plant was a symptomless carrier of the bacteria. In addition, it was found that some varieties such as K20 and K130 were better carriers of the bacteria than others such as Mutike and Banja 2.

Introduction

Pseudomonas solanacearum E.F. Smith, which causes bacterial wilt of many crops, is one of the most important, widespread and lethal bacteria in subtropical and tropical areas. With the exception of *Agrobacterium tumufaciens* (Smith and Towns) Conn, no other bacterial plant pathogen attacks as many different species of plants as does this bacterium (Elliot, 1951; Kelman, 1953). At first it was believed that only Solanaceous species as tobacco, tomato, pepper and eggplants are subject to attack by this wilt pathogen, but the list compiled by Kelman (1953) shows that members of 33 plant families have been found to be susceptible plants.

In Uganda, bacterial wilt was first diagnosed on groundnuts (*Arachis hypogaea* L.) at Bukalasa in 1938 (Simbwa-Bunnya, 1971) where it destroyed over 10% of the total crop. Later in 1963 it resulted in a loss of 60% on the same crop. The same disease was diagnosed on tobacco in Gulu in 1956 (Leakey, 1970) and on potatoes (*Solanum tuberosum* L.) at Namulonge in 1958. There was also a serious attack on tomato at Kabanyolo in 1975 where 95% of the crop was lost (Nairima, 1976). The disease also resulted in 100% loss of the tomato crop which had been planted by the author in the first rains of 1976. Now at Kawanda, Kabanyolo and Namulonge it is almost impossible to grow tomatoes because the disease has spread to most fields.

Realising the seriousness of the disease, the author started a project to study the range of plants affected by *P.*

solanacearum in Uganda. Bean was one of the plants tested as one of the true hosts. During these studies, bean was found not to exhibit symptoms of the bacterial wilt (that is, yellowing, leaf drooping and wilting). However, attempts to isolate the bacteria from the stems and roots gave positive results (i.e. the bacteria could be isolated from these bean plants without symptoms). After isolating the bacteria from five bean plants obtained from three different plots, it was decided that an experiment be set up, using different bean varieties, to study the reaction of the bean plant to *P. solanacearum*.

Literature Review

Kelman (1953) divides the hosts of *P. solanacearum* into two groups:

1. *True hosts*: These include those plants that are susceptible to infection both under natural conditions and artificial inoculation.

2. *Not true hosts*: These include those plants that are infected only by artificial inoculation but are not infected under natural conditions.

Ramos (1969), working in Kenya, divided the hosts of *P. solanacearum* into three categories depending upon the response to inoculation. These categories were defined as follows:

1. *Sensitive hosts*: With these hosts there is a high rate of multiplication of the bacteria followed by early wilting and disintegration of tissues. Wilting is accompanied by massive discharge of bacteria from roots. Both tomatoes and potatoes belong to this category.

2. *Insensitive hosts*: The rate of multiplication of the bacteria in these hosts is less than in a sensitive host. Wilting is not immediately lethal, and the host plant can remain alive in a wilted condition for many weeks. Release of the bacteria commences at the time of wilting and continues for as long as the plant remains alive. Capsicums belong to this category.

3. *Symptomless carriers* : The rate of multiplication of the hosts is relatively low. The hosts show no visual symptoms or very minor symptoms. Dicharge of the bacteria from roots occurs mainly at the time of root deçay and the rate of discharge is relatively low. Smith (1939) during his host-range studies for *Bacterium solanacearum*, found that beans were susceptible to this bacterium both under natural and artificial inoculation. He however found that they were of low susceptibility if compared with other crops like tomato.

Materials and Methods

Soils collected from a bacterial wilt infested field were used as the source of inoculum. This is because *P. solanacearum* is a soil-borne pathogen (Kelman, 1953). This means healthy plants can be infected by this bacteria from the soil, if the soil is infested by this pathogen and if the plants are susceptible.

Soil Collection and Growth of Plants

Soil was collected from different parts of a known bacteria (*P. solanacearum*) infested field at Kawanda Research Station. The soil was mixed thoroughly after collection. It was then put in gunny bags until the following day when it was put in pots. At the time of collection the field had eggplants growing in it.

Medium-sized clay pots were used for this experiment. Seven varieties of beans, namely, K20, Kanyebwa, K130, Kayinja, White Haricot, Mutike (purple) and Banja 2 were used. Tomato (Money Maker) was used as a control and later for pathogenicity tests. The tomato here was used to check on symptom development, that is, if the bean varieties wilted or yellowed as the tomato plants did before wilting.

For each variety (including control), five pots were used. The pots were laid out in completely randomised design with five replicates. That is, each pot was taken as a replicate. In each pot five seeds of the relevant variety were planted, and after germination they were thinned to four seedlings per pot. There was a total of twenty plants per variety.

This experiment was set up in September 1982 and repeated in March 1983.

Sampling and Isolation Procedure

Sampling for isolation was done at weekly intervals from the time the plants were two weeks old. This continued up to physiological maturity. Two plants were sampled at each time. The plants were randomly selected from the pots during sampling.

The bacteria was isolated from the plants using Kelman's medium. Kelman's method (1954) was used in identification of the virulent colonies and the isolation of these from the culture. According to Kelman (1954): "virulent or fluidal colonies are slightly raised, slimy and appear creamy white with pink orange centres. They are rarely truly round and more often irregular in shape." While "virulent colonies are truly round and butyrous and richly pigmented in red and blue-red colours".

Virulent colonies were selected for storage, for pathogenicity tests, after subculturing.

Storage of Cultures

Single distinct virulent colonies from a 48-72-hour-old culture were selected and put on slants of nutrient agar. The stored cultures were used for pathogenicity testing.

Pathogenicity Testing of the Isolates

This was carried out by re-inoculation of the bacteria back to a healthy bean plant of the same variety as the one from which it was isolated. In addition, tomatoes were inoculated with isolates from the different bean varieties. The different bean plants were also inoculated by isolates from tomatoes. For each isolate, twenty plants of the relevant variety in five pots (each with four plants) were used.

The stem-puncture technique was used for inoculation and four-week-old bean or tomato plants were used for the study. The beans and tomato plants for this test were grown in heat-sterilised soil. They were inoculated with a sterile dropper by placing one drop of inoculum in the leaf axil of the third trifoliate leaf from the top. For tomato the third mature leaf from the top was used. A needle was then flamed, allowed to cool for a few seconds and then inserted through the centre of the drop into the centre of the stem about 1-2 cm deep.

Results

The results are summarised in Table 1. All the bean varieties did not exhibit symptoms of bacterial wilt. They were all healthy. Bacteria was, however, isolated from all the varieties, although some varieties had significantly more plants with bacteria than others. During both trials K130 had more plants from which bacteria was isolated than the other varieties. Banja 2 followed closely by Mutike 4 had the least in both trials.

Tomatoes (not included in the table) had all the symptoms of bacterial wilt. By the sixth week all the tomato plants had wilted. During pathogenicity tests when bacteria was re-inoculated back to the healthy bean plant (of the same variety as the one from which the isolate was obtained), no wilting occurred. However, when the bacteria was inoculated into the tomato plants, the results presented in Table 2 were obtained.

Table 1. Response of Seven Varieties of Beans to *Pseudomonas solanacearum*.

Bean Variety	Total No. of plants	No. with bacterial wilt symptoms	Plants from which bacteria was isolated: September - November 1982		March - May 1983	
			Total from which bacteria isolated	Mean[a]	Total from which bacteria isolated	Mean[b]
K20	20	None	15	3.0ab	13	2.6a
Kanyebwa	20	None	10	2.0a	12	2.4a
K130	20	None	17	3.4b	16	3.2a
Kayinja	20	None	8	1.6a	8	1.6ab
White haricot	20	None	10	2.0a	9	1.8ab
Mutike (purple)	20	None	5	1.0a	6	1.2ab
Banja 2	20	None	3	0.6a	2	0.4 b

[a] Data is an average of five replications, four plants per replicate.
[b] Means with a letter in common are not significantly different (P = 0.05) according to Duncan's Multiple Range Test

L.S.D. 0.05 = 1.305
0.01 = 0.963

Table 2. Response of tomato (Money Maker) to *P. solanacearum* isolates from seven varieties of beans.

Bean variety from which isolate was obtained	Total No. of tomatoes inoculated	Total wilted	Percent wilted
K20	20	20	100
Kanyebwa	20	20	100
K130	20	18	90
Kayinja	20	20	100
White haricot	20	20	100
Mutike (purple)	20	20	100
Banja	20	20	100

The table shows that in all cases there was 100% wilting of the inoculated tomato plants except in the case of the isolate from K130 where 90% wilting occurred. None of the bean varieties showed any symptoms of wilt when inoculated with the isolates from tomato.

Discussion and Conclusion

The results indicate that bean (*Phaseolus vulgaris*) is not a true or sensitive host of biotypes of *P. solanacearum* occurring at Kawanda. With the results obtained, bean is one of the symptomless carriers of this bacteria.

Kelman (1953) and Smith (1939) list beans as true hosts in Group I, but with these studies they are found to be in Group II. This means that either the varieties used for this experiment were tolerant to the pathogen, or the biotype to which the bean plant is sensitive is not found in Kawanda soils. There are four biotypes (1,2,3 and 4) of *P. solanacearum* (Hayward, 1964). In Uganda, biotypes 3 and 4 have been isolated from groundnuts at Bukalasa and Kawanda respectively. Ramos (1969) classified the East African isolates into four pathotypes A,B,C and D; pathotype A corresponding to biotype 2, pathotype B and C to biotype 3 and pathotype D to biotype 1.

The results also showed that some bean varieties were better carriers than others. For example, K20 and K130 are much better carriers than Mutike and Banja.

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35649

Review of Field and Stored Product Pest Management of Beans in Ethiopia

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Abstract

This paper reviews haricot beans pest management research in Ethiopia. Results on various control measures against important pests which include *Heliothis armigera, Ophiomyia phaseoli, Tetranychus* sp., and *Callosobruchus chinensis* are reported. Finally, it is emphasised that the significance of these control programmes must be geared to the establishment of integrated pest management. Attempts will also be made to make use of natural enemies, resistant varieties, trap crops and cultural practices such as intercropping, sowing dates and optimum plant density to develop an integrated pest control programme.

This paper deals with the highlights of research findings regarding control measures of African bollworm, bean fly, spider mites, and bean bruchids and suggestions for future work on haricot bean pests. Brief accounts of the results under each pest and various aspects of control methods studied are given below.

Introduction

Haricot bean (*Phaseolus vulgaris*) is one of the most important food legumes grown both for domestic needs and for export. It is grown in the intermediate (1500-1800m) and low elevation (below 1500m) areas of Ethiopia. From 1960 to 1980, an average of more than 56,000 metric tonnes of haricot bean was produced from over 78,000 ha annually with a yield level of less than one ton/ha (Ministry of Agriculture, 1982). The major constraints contributing to the low yield of haricot beans include diseases, weeds and insects. Of these production constraints, insect pests are of paramount importance in the production and expansion of this crop. In Ethiopia extensive surveys have been made to know the distribution and importance of the insect pest and natural enemy complex of haricot bean (Tsedeke, 1984 and Tsedeke *et al.*, 1982). To date, a total of well over 40 species of insects has been identified, of which the African bollworm (*Heliothis armigera*), bean fly (*Ophiomyia phaseoli*) and spider mites (*Tetranyches* sp.) are the key pests of haricot bean in the field and the cowpea bruchids (*Callosobruchus* spp.) are important in stored bean which warranted full fledged research. The pest status of the remaining insects is either sporadic, minor or uncertain.

African Bollworm Control

Chemical Control

Experiments involving four ultra-low-volume insecticides were compared at Awassa and Nazreth IAR centers for two consecutive seasons. Results of these studies have been published (Tsedeke and Ferede, 1981). The insecticides were two levels of the standard insecticides, endosulfan and one level of fenithrothion, selecron and cypermethrin. Among the insecticides tested, cypermethrin at the rate of 150 g a.i/ha gave the most effective control of African bollworm.

Trap Cropping

Trials on the possible use of trap crops in the integrated management of African bollworm were carried out at Nazret. Results of trap cropping experiments have been presented earlier (Tsedeke, 1984; Tsedeke and Ferede, 1986). A brief summary of selection of the best trap crop and appropriate combination of the main crop and trap crop are given below. A trial to determine the best trap crop was carried out between the 1981 and 1983 cropping seasons. The candidate trap crops were hyacinth bean, lupin, maize, pigeon pea and sunflower. Results obtained from this experiment indicated that all trap crops attracted significantly higher African bollworm eggs and larvae than haricot bean. Lower percent of pod damage occurred in maize treated plots. Meanwhile in a separate non-replicated observation trial where haricot bean was interplanted with maize (a trap crop), there were eighteen African bollworm eggs and larvae on maize for every egg and larva on haricot bean (Tsedeke, 1984).

During the 1984 and 1985 seasons, experiments to establish appropriate combinations of haricot bean and maize (trap crop) were carried out. The effect of insecticide application was also tested in this trial. It was recommended that strip cropping of maize with haricot bean at 10 m intervals and spraying maize strips with cypermethrin (100 g.a.i/ha) at peak flowering of haricot bean be practised in the integrated pest management of African bollworm.

Spacing

An experiment to determine the effect of spacing on the population of African bollworm was carried out at Nazreth for two consecutive seasons. Two varieties (Mexican 142 and Negro Mecentral), three inter-row spacings (40, 50 and 60 cm), and three plant populations (100, 300 and 500 thousand plants/ha) were tested at Nazreth during the 1984 and 1985 cropping seasons. There was no effect of varieties and inter-row spacings on African bollworm infestation. However, infestations decreased significantly with plant population (Ferede and Tsedeke, 1986).

Parasitoids (Biological Control)

Surveys have been concentrated on the collection of parasitoids and predator species. The predators are polyphagous whereas the results of the parasitoid species collected are presented earlier (Tsedeke, 1984). The following are the species collected: *Charops spinitorsus* (Hymenoptera Ichneumonidae), *Euplectrus laphygmae* (Hymenoptera Eulophidae), *Linnaemya* sp. *Palexorista* sp. and *Voria ruralis* (all are in the order Diptera and family Tachinidae).

Bean Fly Control

Chemical Control

Experiments were carried out to identify seed dressing insecticides that are effective against bean fly at Kobo and Mekele (Ferede, 1984). One level of aldrin 40% W.P. and three levels of carbofuran 35% liquid were tested. Carbofuran 35% at the rate of 28.75 g/kg of seed appeared most effective in reducing infestation and increasing grain yields, although it exhibited some degree of phytotoxicity.

Sowing Date and Variety Studies

Four varieties of haricot bean (Black Dessie, 15-R-42, 15-R-52 and Mexican 142) were planted at ten-day intervals, from June 10 to July 20 for two and three consecutive seasons at Kobo and Mekele, respectively. Infestations tended to be reduced and seed yield improved by early planting. There were no differences among varieties in bean fly population nor in seed yields (Greathead, 1975).

Spacing

Two varieties (Mexican 142 and Negro Mecentral), three inter-row spacings (40, 50 and 60 cm) and three plant populations (100, 300 and 500 thousand plants/ha) were tested at Melkassa during the 1984 and 1986 seasons. Results were presented earlier (Ferede and Tsedeke, 1986). There was no effect of varieties and inter-row spacings on bean fly infestation. However, infestations tended to be greatest at the smallest population density (100,000 plants/ha).

Natural Enemies Surveys

Surveys have been made to determine the parasitoid and predator species of bean fly. It has been reported that four species of hymenopterous parasitoids have been recorded (Ferede, 1986; Tsedeke, 1984). Of the parasitoids recorded on bean fly, *Opius phaseoli* (Fisher) (Hymenoptera: Braconidae) is of particular significance as it is one of the two important *Opius* species giving effective control of the pest elsewhere (Greathead, 1975).

Varietal Screening

Thirty five lines of haricot beans were evaluated for their resistance to bean fly for two consecutive seasons. The results have been presented earlier (Ferede, 1986). Bean fly infestation ranged from 12 to 38%. The varieties showing the least infestation were Tengeru 16-01 and Acc. No. 309747. In the 1986 cropping season 1640 accessions from Centro Internacional de Agricultura Tropical (CIAT) and local selections at Melkassa, and 206 entries included under various nurseries at Awassa were evaluated for bean fly resistance. Results have been reported by Ferede. A brief summary is given below.

In Melkassa, 110 accessions showed low damage scores (less than two). Eleven percent of the accessions carried a very low number of larvae and/or pupae per plant. Thirty-six accessions had low number of larvae/pupae per plant and low damage score. In Awassa three sets of trials were evaluated. In preliminary nursery, where up to 100 entries were tested in non-replicated trials, a lower percent of bean fly damage was recorded for 13 entries and 10% of the entries supported 0-1 larvae/pupae per plant.

For the replicated trials in advanced nursery the range of bean fly damage varied from 36 to 76%. M-112, Red Wolaita and 6R-395-08 had lower percent of bean fly, whereas in further evaluation nursery, differences in bean fly damage among varieties ranged from 20 to 67%. The varieties BAT 867-1C-1C, BAT 260-2C (68 VEF 983-2), BAT 1061-1C-1C exhibited low bean fly damage (Ferede, 1986).

Spider Mites Control

The importance of spider mites is limited to irrigated haricot beans, and since production of this crop is during the rainy season, only an observation trial has been carried out using insecticides. This has been reported earlier (Tsedeke, 1971; Tsedeke and Kemal, 1986). Satisfactory control of the pest has been achieved with 0.025 to 0.05% a.i. chlorobenzilate sprays.

Control of Bean Bruchids

Three levels each of lindane, methacrifos and primiphos, methyl were evaluated for bean bruchid control on stored haricot bean between 1981 and 1983. Results have been published (Tsedeke, 1985). It was indicated that primiphos-methyl gave the most effective control. Higher levels of methacrifos also gave good control but for a shorter duration (two to three months).

Looking Ahead

Most of our efforts in the haricot bean pest programme are geared towards developing IPM. To achieve our goal, studies on varietal resistance to bean fly will concentrate on evaluation of genotypes with promising performance over locations. Attempts will also be made to select materials for resistance to bean bruchids on stored haricot bean in close collaboration with CIAT entomologists and breeders. Furthermore, research on cultural practices such as sowing date, spacing and trap cropping would receive due attention on major pests of haricot beans. Emphasis will also be given to further survey, collection and identification of insect pest species and their natural enemies and refinement of our sampling methods.

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Grain Legume Entomology in Somalia

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Introduction

Cowpea (*Vigna unguiculata*) is the most important legume crop in Somalia, and it provides the major source of protein and daily diet. It is cultivated throughout the regions of Somalia, being irrigated or rainfed, especially in the southern and central regions. Beans (*Phaseolus vulgaris*) are grown to a much lesser extent and, as research on this crop is only just starting, it is not discussed here.

Most of the crop in Somalia is grown as an intercrop with cereals like maize and sorghum, and it forms an essential component of various cropping systems. The average cowpea yield under farmers' conditions ranges from 200-300 kg/ha. Although this extremely low average yield of cowpea is partly due to intercropping, low plant populations and disease and insect pests are other major factors.

Cowpea is attacked by several diseases and insect pests. The occurrence and severity of individual diseases and insect pests vary from place to place, season to season and the stage of plant growth. In Somalia we have two seasons, Gu from April to June and Der from September/October to December. Gu is more humid and rainy than Der season; therefore the infestation of disease and insect pests in irrigated areas is high in Gu season. Farmers like to grow cowpea and other pulses in Der season because of less infestation of pests.

Importance of Cowpea Crop

Cowpea crop comes first in importance as a legume food crop in Somalia. Also, the vegetative parts are used for animal feed in the dry seasons. It makes a variety of local family dishes like boiled cowpea (*Ambullo*), roasted cowpea (*Falfaliir*) and fried cowpea (*Bajiya*). With the intensive rural-urban migration cowpea has become the sole candidate for filling the protein gap of the poor migrated rural mass since the majority of them cannot afford the daily needs of their traditional daily protein (meat and milk).

In the last eleven years the area under pulses cultivation has fluctuated between 18,800 ha to 28,900 ha which can be cropped twice a year under favourable conditions. The crop grows under both irrigated and rainfed conditions. Cowpea and mungbean are the most common pulses.

Table 1. Production of Pulse Crops in Somalia, 1975 - 1986.

Year	Cowpea and Mungbean Production (tonnes)
1975	9.4
1976	9.8
1977	10.2
1978	10.1
1979	8.2
1980	9.3
1981	12.6
1982	15.0
1983	20.8
1984	15.0
1985	15.0
1986	12.7

Insect Pests

The major insect pests that attack cowpea are leaf-chewing beetles, leaf hoppers, aphids, thrips, pod-porers, coreid bugs and seed weevil. Maximum damage is caused by thrips, *Maruca* pod borer, pod-sucking bugs and cowpea seed weevil.

Most of these insect pests attack the crop at three different stages:

1. Field level: That could be high if condition is favourable for insect infestation, especially humid and rainy conditions.

2. Transition: If the grains do not dry properly after harvest, the infestation of the insect in this stage could be serious.

3. Store: In storing of contaminated grains, the attack of grain weevilss higher and more serious than in the other two stages.

Insects that attack stored leguminous crops belong to the family Bruchidae which confines its attacks to pulse grains and causes severe damage to leguminous crops. This is classified as follows.

The first group attack green pods in the field and cannot infest. Adults may remain inside dry seeds in storage for several months until the next season of cultivation. Adults may then come out from the seeds when sown. Thus, there is only one generation a year.

The second group of insects infests stored seeds, and there are several generations every year. Being polyphagous and polyvoltine, this group is the most important and most destructive. Among this group are the cowpea weevils.

Storage Methods

In Somalia we have no effective way of storing the grain legumes, cowpeas and mungbeans, but there are traditional methods that reduce the infestation of bruchids that attack the stored grain legumes. Some of these methods are as follows:

1. Grains mixed in ashes
   Somalian farmers used to mix grain legumes into ashes in order to reduce the great losses caused by cowpea weevils.

2. Roasted cowpea
   One of the good methods of cowpea preservation is roasting In this method the cowpeas are roasted with heated sand, and testa is removed. This method preserves the cowpeas for longer than six months.

3. Mixing with oils
   In this method of storing, the cowpea grains are mixed with oils to cover the surface of the seed coats. Grains can be preserved for a long time.

Materials and Methods

A study was conducted to find out if oils of soybean, groundnut, sesame, sunflower and Ghee would protect cowpeas against weevil. Two cowpea varieties were used, namely local and TVU-150-1C; the moisture content of the local variety was 12.77% and the other was 11.40%. The grains of the local variety were larger than the TVU-150-1C. The colour of the local was red, that of the other was grey. The experiment was conducted in the laboratory; the temperature in the laboratory was about 28 C and the relative humidity was around 80%.

The treatments were five oils, one control and two varieties replicated three times; 36 jars were needed. The jars were semi-open and transparent. In each one of 18 jars was put one kg of seeds of one variety. For every oil a fixed dose of 5 ml/kg of seed was used. The desired amount of oil was added to the kg of cowpea seed in the jar. The whole was mixed and shaken.

Results and Discussion

Comparison of the local variety to the introduced variety (TVU-150-1C), as shown in Table 2, indicates that it is more susceptible to weevil damage for all treatments. As far as the oils are concerned the best protection was provided by sunflowers, ghee and groundnuts. Soybean and sesame gave the least protection, especially in the case of the more susceptible local variety. However, they were superior to the control.

There was a positive relationship between damage and the reproduction of the cowpea weevil. Highest reproduction was attained in the untreated control, followed by soybean and sesame.

The analysis of variance was carried out for the local variety which has shown the highest susceptibility and indicated a highly significant difference (P = 0.001) due to oil treatment. Further comparison of the means for oil treatment indicated that sunflower, ghee and groundnut are superior to the treatment but are not significantly different among themselves. Sesame was slightly but not significantly better than soybeans. However, all oil treatments were significantly better than the control.

Summary and Conclusions

Cowpea, an important grain legume in Somalia, suffers from cosiderable damage in storage by cowpea weevil. The scope of this study was to compare the storage damage on two cowpea varieties, namely, the local and introduced TVU-150-1C, treated with various oils. Previous studies at IITA have shown that some vegetable oils protect cowpea against weevil damage.

A literature review of the economic importance, insect damage and preservation methods was made prior to the experiment with oils. The undamaged of the two varieties were treated with oils of soybean, groundnut, sesame, sunflower and ghee. Three was an untreated control. Periodic scores were made at an interval up to 200 days.

Table 2. The Influence of Oil Treatments on Storage Damage of Cowpea Varieties.

Treatment	Infestation period (days)	Local Variety		Variety Tvu-150-1C	
		Mean dead adults	Mean damaged grain/1000	Mean dead adults	Mean damaged grain/1000
Soybean	80	5.3	0.0	5.7	0.0
	40	6.0	9.7	6.0	0.0
	60	6.3	13.7	6.0	0.0
	80	18.7	34.0	7.3	1.0
	100	32.3	66.0	7.7	8.3
	120	61.0	81.7	14.3	16.0
	200	81.3	237.3	23.3	26.0
Groundnut	20	5.7	0.0	5.7	0.0
	40	6.0	6.0	6.0	0.0
	60	6.7	6.7	6.0	0.0
	80	7.3	11.0	7.0	0.0
	100	7.3	13.3	8.0	0.0
	120	8.7	18.3	8.7	7.3
	200	18.7	50.7	11.7	27.7
Sesame	20	5.7	0.0	5.0	0.0
	40	7.0	10.3	6.0	0.0
	60	9.7	15.3	6.7	0.0
	80	12.0	18.0	9.0	0.0
	100	12.7	21.0	9.3	0.7
	120	19.3	32.7	9.3	12.0
	200	40.3	163.3	14.7	29.3
Sunflower	20	5.3	0.0	6.0	0.0
	40	5.7	5.7	6.0	0.0
	60	6.3	7.0	6.0	0.0
	80	7.0	7.3	7.7	0.0
	100	8.0	8.7	7.7	0.0
	120	8.3	11.7	8.0	0.0
	200	13.3	26.3	8.0	0.0
Ghee	20	5.7	0.0	6.0	0.0
	40	6.3	5.3	6.0	0.0
	60	7.0	8.7	6.0	0.0
	80	7.3	10.7	7.0	0.0
	100	7.7	14.0	8.0	0.0
	120	8.0	18.7	8.0	0.7
	200	9.7	34.7	8.7	1.0
Control	20	4.7	0.0	5.0	0.0
	40	15.3	40.3	14.0	0.0
	60	20.3	65.7	19.7	52.0
	80	40.0	108.7	25.3	67.3
	100	75.3	201.3	30.7	113.3
	120	94.0	229.3	42.0	166.0
	200	143.3	427.3	51.3	210.0

Experimental data indicated that the introduced variety TVU-150-1C stored well in comparison to the local variety. All oil treatments provided a significantly lower degree of cowpea weevil reproduction and hence better damage control. This is an indication that the storage life of cowpea could be extended.

The sequence of effective cowpea weevil control was sunflower, ghee, groundnuts, sesame, soybean, control. Therefore, the outcome of this study indicates that some of the introduced Nigerian material may be more resistant, and preservation of all cowpea seed may be prolonged by vegetable and animal oil treatment.

The mechanism of resistance of the variety TVU-150-1C may be due to hard seed coat; however, this requires further study. The mechanism of the influence of oils also needs further study.

A Strategy for Maximising Bean Yields in Nematode-Infested Soils

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Introduction

Beans (*Phaseolus vulgaris* L.) are an important component of the diets of virtually everyone in Uganda. They are eaten as leaves, immature pods, green or dry seeds. They are an important source of dietary protein. According to the 1982 IDRC report (Anon, 1982), about 0.4 m hectares of beans were grown in 1980. Average yield was 500 kg/ha and total production was estimated to be 180,000 MT. Production on peasant holdings may be as low as 200 kg/ha. However, other reports (Anon, 1986) show that much higher yields of 900-2000 kg/ha have been obtained on experimental plots. One inference that may be made from these data is that the potential for raising yields on farmers' level, and hence total production, is high. This is an area of research worth pursuing especially at this time when animal by-products as sources of protein are too expensive and beans are being developed into an export crop.

There is generally a dearth of information concerning major production constraints for beans. However, information available attributes low yields in beans to lack of suitable varieties, lack of extension service, poor marketing infrastructure, and disease and pest pressure (Anon, 1986). Beans respond well to nitrogenous and phosphate fertilisers. This suggests that low soil fertility in potentially good production areas has been another limiting factor.

Most reports on pests of beans (Anon, 1978, 1985; Dunbar, 1975) tend to emphasise damage by insects; they do not mention nematodes, and yet these are also important pests on the crop. This is perhaps because the damage by nematodes is less conspicuous, and in Uganda there is presently survey information to show the range of nematode pests that attack the crop. According to Johnson and Fassuliotis (1984) there are many nematodes that are associated with leguminous vegetables. Beans alone are attacked by 24 nematode species, but of these, only root-knot nematodes, *Meloidogyne* species and root lesion nematodes, *Pratylenchus* species are economically the most important. Whitehead (1969) found *M. javanica* and *M. incognita* widely distributed in many soil types in Uganda. Bafokuzara (1975) has identified some species of root-knot nematodes on beans in Uganda.

Meloidogyne species are responsible for yield losses in beans of 50-90%, and *Pratylenchus* species for 10-80% (Johnson *et al.*, 1984). Sasser (1979) puts the magnitude of damage in beans in the tropics to 28%. Ngundo and Taylor (1974) obtained 45-60% increases in yields of Kikara and Mexican 142 bean cultivars, with preplant applications of soil fumigants, D-D (336. 8 L/ha broadcast, and 224.5 L/ha in the row) and EBD (67.3 L/ha broadcast and 44.9 L/ha in the row). These latter data also constitute a quantitative assessment of damage that might be expected when no nematicide is applied. The yield losses just reported may be much higher where these pests interact with other soil-inhabiting, disease-causing organisms such as fungi and bacteria or where the crop is cultivated intensively. These data suggest a need for controlling these pests for successful production of beans (where the nematodes do occur).

Methods and Materials

Proper pest control should ensure a profit to the farmer and avoid environmental pollution with pesticide residues. To achieve this demands use of more than one control measure, i.e. an integration of control measures. Initial survey information in Uganda (Patel and Bafokuzara, 1969, unpublished) indicates that under some conditions, some varieties of beans and other leguminous crops growing in root-knot infested areas do not show any serious damage symptoms. Therefore a study being conducted at Kawanda seeks (1) to identify resistant germplasm among beans, other leguminous crops, local and exotic vegetables and (2) to develop management strategies for major root-knot nematodes. A scheme as to how control of a pathogenic nematode may be achieved, using a variety of control measures, in a three-year cropping programme, is shown in Table 1.

The *M. incognita* race I being used was raised from a single eggmass isolated from a tomato plant collected from a field at Kawanda. The nematodes were multiplied and maintained on tomato (*Lycopersicon esculentum* L.) Cv. Money Maker, in a greenhouse. Identification of the race made use of the NCSU Differential Host Tests. The experimental design was a randomised block. Eggmasses for the nematodes that were used in each inoculation were extracted from infected roots and hatched in demineralised water contained in a watch glass, over 24 hours, in an incubator maintained at 25^{o} C; 12-20-day-old seedlings of each test plant in 20 cm diameter earthenware pots of heat-sterilised soil were inoculated with 5000 L2 larvae of *M. incognita* race I. Each treatment was replicated ten times. Plants were evaluated 45 days after inoculation. Each root system was stained with Phloxin B to facilitate counting of eggmasses and galls. Plants were categorised into resistant (R), tolerant/intermediate (T/I) and susceptible (S), according to the standard ratings of the NCSU--based International Meloidogyne Project (IMP) where,

0 = no gall or eggmass
1 = 1 - 2 galls or eggmasses
2 = 3 - 10 galls or eggmasses

3 = 11 - 30 galls or eggmasses
4 = 31 - 100 galls or eggmasses
5 = over 100 galls or eggmasses
Here R = 0-1, T/I = 2-3 and S = 4-5+

Tests that gave negative results were repeated to ensure they were not due to chance.

Results

No resistance has been shown by any of the bean cultivars so far tested (Table 2). This includes some of the most popular and important cultivars in Uganda, namely Kanyebwa, K 20, and Mutike; Khaki was intermediate in its reaction. Soybean, Cv Kabanyolo I, though intermediate in its reaction, showed marked hypersensitivity. Brownish (dead) tissues developed mainly around the nematode's head; this apparently prevented the larvae from feeding inside the root. Many larvae were encountered that apparently had not developed beyond the sexually-undifferentiated second stage. These observations emphasise that:

1. Root-knot nematodes are a serious disease problem on the leguminosae and could be a limiting factor in the production of beans in many parts of Uganda.

2. It is important to ensure that the fields where beans are to be grown are not heavily infested by pathogenic nematodes. Thus field soil should be analysed before planting is done.

3. Crops to be grown in sequence with beans should be selected carefully to avoid a build up of nematode populations to economic injury level. Avoid repeated use of infested land for growing susceptible crops.

The present programme of screening is to be continued. Other aspects of resistance, including rate of larval penetration into host roots, fecundity, host cell reaction and source of resistance, are to be investigated.

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Table 1. Effect of Cropping Sequences on Nematode Population in a 3-year Cropping Programme

Crop Sequence	Year 1 Seasons 1	2	Year 2 Seasons 3	4	Year 3 Seasons 5	6
A	Sa	S	S	S	S	S
B	R	S	R	S	R	S
C	R	R	S	R	R	S
D	S	R	R	R	S	R
E	S	R	R	R	R	S
F	R	R	R	R	R	R
G	R	R	R	R	R	R

Notes: (a) S = Susceptible host
R = Resistant plant
(b) Crop sequence A: Stimulates nematode population build up, use of nematicides or other control agent every other year is necessary.
Crop sequence B: use of a control measure may be necessary.
Cropping systems: C - G suppress nematode population build up; use of control agent not necessary.

Table 2. Suitability of Various Crops as Hosts of *M. incognita*

Species	Level of infestation: No. of galls	No. of eggmasses	Resistance category	Susceptibility rating
1. *Phaseolus vulgaris*				
Cv.K20	100+	100+	5	Highly suscepti
Cv.130	100+	100+	5	" "
Mutike	45	38	4	Susceptible
Khaki	23	17	3	Tolerant
Kanyebwa	100+	100+	5	HS
2. *P. unguiculata*				
Cv. Mimba	100+	100+	5	HS
3. *P. lablab*	100+	100+	5	HS
4. *P. max.*				
Cv. Kabanyolo 1	22	9	2-3	T/I
5. *Arachis hypogea*				
Cv. Roxo	0	0	1	Resistant

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SUMMARY OF DISCUSSION

The use of varieties of differential susceptibility is a useful way of understanding disease races, e.g. of bean rust and anthracnose. As these differentials are used only as a research tool, it does not matter that their grain types may not necessarily fit local market preferences. Adequate greenhouse facilities may be needed to preserve the qualities of the differential varieties.

Plant pathologists have a responsibility to develop practical inoculation techniques and to ensure that the results are incorporated into breeding or variety selection programmes.

Although oil treatments may appear to be expensive for grain storage, the high cost of grain legumes during the dry season in Somalia is expected to make this worthwhile. The quantities of oil required are small (5 ml/kg or less).

As root-knot nematodes are reported to occur throughout Uganda (except possibly Kigezi), and have many hosts including weeds, field tests will be required to confirm preliminary greenhouse control experiments on the use of crop rotation. Also, estimates of field crop losses to nematodes are lacking from most countries; symptoms are often difficult to recognise.

SESSION V: NITROGEN FIXATION, PHYSIOLOGY, AGRONOMY AND WEEDS

Effect of Inoculation and Nitrogen Fertilisation on Yield of Common Bean in Ethiopia

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Abstract

A mixture of three strains of *Rhizobium phaseoli* (TAL 182, 1383 and 1376) from NifTAL, and nitrogen fertiliser (urea) at the rate of 100 kg/ha were used to study the response of *Phaseolus vulgaris* to different source of nitrogen. A control was used for comparison and the treatments were tested with and without 100 kg/ha of P2O5. The trial was conducted for two consecutive years, 1981 and 1982, using randomised complete block design with four replications at Melkassa Research Centre. Nitrogen fertiliser application significantly (P = 0.05) depressed the nodulation of *P. vulgaris* in both years. The difference in yield of the treatments was significant (P = 0.05) during the first year but not in the second year. The highest mean yield was recorded for the treatment of 100 kg/ha N with 100 kg/ha P2O5. P2O5 application has induced significant (P = 0.05) effect on both nodulation and mean yield. *P. vulgaris* showed much response to nitrogen fertiliser and less to inoculation.

Introduction

Different researchers showed the response of *P. vulgaris* to inoculation and nitrogen fertiliser. Avilo (1976) summarised 50 independently conducted experiments of *P. vulgaris* response to nitrogen fertilisers. Half of the experiments did not show response to nitrogen fertiliser applications. Graham (1978) reported that inoculation of bean with *Rhizobium phaseoli* has not been a viable alternative to nitrogen fertilisers in Latin America because most commercial varieties do not respond to inoculation. On the other side, Souza (1969) and Lopes (1974) have found that profusely nodulated *P. vulgaris* could fix adequate nitrogen to meet the nitrogen requirements of the plant. The response of *P. vulgaris* to inoculation under Ethiopia conditions is not known; thus the main objective of this study was to investigate the response of *P. vulgaris* to inoculation and nitrogen fertiliser.

Materials and Methods

Seeds of *Phaseolus vulgaris*, variety Mexican 142, were inoculated with the mixture of three strains of *Rhizobium phaseoli* which was developed by NifTAL. The inoculation of seeds was done two hours before planting. The number of cells in the carrier was estimated to be 108 three days before planting. It was determined by planting serially diluted cells on yeast extract manitol Agar (Vincent, 1970).

The six treatments used in the trial were: control, 100 kg/ha N, inoculated seeds; 100 kg/ha P2O5; 100 kg/ha P2O5 + 100 kg/ha N, and 100 kg/ha P2O5 + inoculation urea and triple superphosphate (TSP) were used as a source of nitrogen and P2O5 respectively. Split application was used for urea, 25 kg/ha during planting and 75 kg/ha during vegetative growth stage. TSP was applied four days before planting.

The size of each plot was 2.4 m x 7 m with a spacing of 60 cm between rows and 5 cm within rows, giving a population of 333,333 plants/ha. At the time of 50% flowering stage, ten random plants from each plot were uprooted and nodules were checked for effectiveness of nitrogen fixation, nodulation pattern and fresh weight. At the time of maturity, beans were harvested and the seed yield from the two middle rows were taken to estimate the yield.

Results and Discussion

Table 1 shows the effect of inoculation and fertiliser on the dry bean yield and nodule fresh weight. There was no interaction between treatments and year, indicating that the magnitude of the increase in yield of *Phaseolus vulgaris* due to inoculation was essentially the same in each year.

Nodule Fresh Weight

Nodule fresh weight (mean 6 mg/10 plants) in both years, 1981 and 1982, showed that application of nitrogen fertiliser (urea) at the rate of 100 kg/ha significantly ($P = 0.05$) depressed the nodulation of *P. vulgaris*. Weber (1966) had found similar results to the present finding in that the nodulation of beans decreased rapidly with the increase in nitrogen fertiliser. The reason for the depressing effect of nitrogen fertiliser on nodulation is not clearly known. Cartwright (1966) suggested that the adverse effect of combined nitrogen on nodulation is due to the accumulation of unsequestered nitrogen compounds and a depletion of carbohydrate generally within the root tissues rather than the local effect of any particular nitrogen compound. Hinson (1975) reported that nitrate reduction inhibits indoleacetic acid (IAA) production, necessary for nodule initiation.

Table 1. Effect of inoculation and fertiliser application on bean yield and nodulation under field conditions.

Treatments	Dry bean yield kg/ha 1981	1982	mean	Nodule fresh weight mg/10 plants 1981	1982	mean
Control	1612 d	2024 a	1818	270	250	260
N (100kg/ha)	2387ab	2459 a	2423	001	010	006
Inoculation	1912cd	2229 a	2070	140	290	215
P2O5 (100kg/ha)	2000 c	2052 a	2026	380	290	335
P2O5 + N (100kg/ha each)	2758 a	2177 a	2467	030	010	020
P2O5 100kg/ha + inoculation	2208bc	2247 a	2227	350	250	300
Mean	2146	2198	2172	195	183	189

Means followed by the same letter are not significantly different at 5% level of probability by Duncan's multiple range test.

P2O5 application at the rate of 100 kg/ha improved the nodulation of the plants by 22% compared with the control. The nodule fresh weight in the inoculated plants without P2O5 was lower by 21%. However, those nodules in the inoculated plants increased the grain yield by 14% indicating that they were more effective than the native strains of *R. phaseoli*. P2O5 application also improved by 40% the nodulation of the inoculated plants without P2O5 (mean of two years). Phosphate is an important element needed for satisfactory nodulation. The present finding is in agreement with that of De Mooy (1966) and Jones (1977). De Mooy (1966) showed the dominant role of phosphate fertiliser for optimum nodulation of soybeans. According to him, 300 (ppm) of P2O5 doubled the fresh weight of nodules, and optimum nodulation generally occurred at 400-500 ppm of P2O5, which is beyond economic application under field conditions. Jones' (1977) finding indicated that application of P2O5 at 60 kg/ha gave a maximum response of nodulation.

Dry Bean Yield

Significant (P = 0.05) increase of grain yield due to fertiliser application was observed in 1981. During the next year the difference in yield among the treatments was not significant.

The 1981 result revealed that nitrogen fertiliser (100kg/ha) with and without P2O5 fertiliser induced significant (P = 0.05) yield increase compared with the control. The estimated magnitude of this effect was an increase of 775 kg seed/ha and 1146 kg seed/ha in the treatments 100 kg/ha N and 100 kg/ha N + 100 kg/ha P205 respectively. The significant difference in yield between the control and 100 kg/ha N indicated that the local strains of Rhizobium was not able to fix nitrogen to satisfy the needs of the plants.

This result is in agreement with the findings of Amare (1982), Graham (1978) and Vincent (1974), and it also contradicts the report of Souza (1969). Amare (1982) reported that locally isolated strains of *R. phaseoli* at a higher rate of inoculation fixed about 18 kg/ha N, which was below the need of the plants. Graham (1978) and Vincent (1974) had also reported that *P. vulgaris* is inferior in nitrogen-fixing capacity. Souza's (1969) work contradicted the present finding in that he demonstrated that efficiently nodulated bean plants can fix nitrogen under field condition at rates equivalent to its nitrogen requirements. The disagreement of Souza (1969) with the present finding could be due to the difference in strains used in the trials, soil fertility, ecology and other factors affecting nitrogen fixation.

Inoculated plants in both treatments, with and without 100 kg/ha P205, yielded more seed than the control. In the treatments of inoculation + 100 kg/ha P205 the yield difference (596 kg/ha) was significantly ($P = 0.05$) higher than the control. But the yield difference (300 kg/ha) of the inoculated plants from that of the control was not significant ($P = 0.05$). The additional yield gained from the inoculated plants was due to the nitrogen-fixing abilities of the three mixed strains of *R. phaseoli*. Those strains were also not strong enough to fix nitrogen according to the need of the plants, because plants with 100 kg/ha N gave significantly ($P = 0.05$) more yield than the inoculated ones. However, they are better nitrogen fixers as compared to the local strains. This finding indicates that there is a possibility of improving *P. vulgaris* nitrogen fixing ability by selecting better strains.

In 1982, the differences in yields among treatments were not significant. The possible explanation for that could be that the trial was conducted in the area where P205 was applied for the preceding crop, and the residual effect of P205 affected the yield positively. The control and 100 kg/ha P205 gave similar yield, whereas nitrogen fertilisers and inoculation tended to increase yields slightly (Table 1). The two years' mean yield showed that *P. vulgaris* responded more to nitrogen fertiliser than to inoculation. The introduced strains of *R. phaseoli* increased yield more than the local strain, indicating they fixed more nitrogen.

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Preliminary Investigations on Symbiotic Nitrogen Fixation in Beans Grown on a Ferralitic Soil at Kabanyolo, Uganda

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Abstract

Bean (*Phaseolus vulgaris*) yields in Uganda are very low. This is mainly due to unavailability of nitrogen for crop growth. Nitrogen fertilisers are expensive for bean farmers. The feasible alternative is exploitation of benefits from Rhizobium-bean symbiosis. Preliminary results of bean field trials to be run for two years at Makerere University Farm, Kabanyolo, are reported. Isolation of native Rhizobium for beans is suggested.

Introduction

Despite all the efforts put into improving bean yield through breeding and extension programmes, the crop yield has stayed very low. According to Leakey (1970) the average yield is 560 kg/ha for beans in pure stand and 390-450 kg/ha for mixed crops. These very low yields may be mainly due to farmers' tendancy to grow beans in fields which have been previously used for other crops, for they feel the crop does not require much from the land in terms of fertility. Beans may only be grown on newly opened land when the crop is to be interplanted with other crops. However, Mukasa (1970) reported farmers to be planting beans on any type of soil, and the crop performed well except on very acid soils; he further noted that the crop requires a high level of fertility.

We consider that bean yields in Uganda can be improved by improving soil fertility status, particularly with provision of adequate nitrogen to the crop. Beans require a supply of nitrogen for better yields. This is evident in results obtained in a factorial fertiliser trial in Kariri on clay loam soils; the crop gave 20% seed yield over a control of 1227 kg/ha. On the brown clays of Bukomero, beans gave 20% seed yield over 1289 kg/ha in response to nitrogen applied at 250 kg/ha N as sulphate of ammonia. This nitrogen treatment gave a better response than when interreacted with 125 kg/ha of sulphate single superphosphate (Fertiliser Development Extension Scheme, Kawanda, unpublished) showing that the increase was due to nitrogen not sulphur.

Nitrogenous fertilisers are very expensive for farmers of Uganda. At the same time Acland (1971) and Stephens (1967) suggested that beans in Uganda nodulate poorly and subsequently fix little nitrogen. Anderson (1973) reported that poor bean nodulation and lack of nitrogen fertiliser response in East African soils was due to inadequate liming, sulphur, phosphorus and potassium. Therefore it would appear that with a fair soil pH above 5.2 and application of single superphosphate (available in Uganda), bean fields may be improved by exploiting the benefits from successful Rhizobium-bean symbiosis, principally through inoculation prior to planting. In this connection Zake and Nkwiine (1981) compared ash and $CaCO_3$ as liming materials on beans and observed better response with the ash. This was attributed to the higher content of potassium and a greater base balance in the ash.

Sakala (1984) in Zambia found that inoculation in combination with 20 kg/ha N increased the yield of beans over the control by 73%, 19% and 50% in varieties of Carioca, Mexican 142 and Misanfu respectively. A great number of nodules, together with increased nodule weight were obtained in the absence of nitrogen fertilisers. In East Africa, de Souza (1969) and Stephens (1971) obtained no significant yield responses due to inoculation of beans with effective strains of *R. phaseoli*. Further, Stephens reported yield responses to the application of ammonium sulphate rather than urea to beans at Kawanda; de Souza, at Njoro reported a negative interaction between inoculation and nitrogen treatments. However, Ssali and Keya (1982) observed positive response of beans to nitrogen fertiliser "Starter" dose.

In Ethiopia, Amare and Birhane (1984) reported varietal differences in the amount of nitrogen fixed by beans which was generally low, estimated to be 3.1 to 17.2 kg/ha N. They also noted increases in soil nitrogen in inoculated plots at high rates of inoculum of 6 x 104 cells per seed and concluded that inoculation with effective strains of *R. phaseoli* at that rate improved seed quality, nitrogen fixation, grain yield and soil fertility. Legumes like soya beans, which fix large quantities of nitrogen, are known to nodulate early, and the nodulating process continues beyond flowering. For beans, however, the period of nodulation is said to be one of the limiting factors to the quantity of nitrogen fixed. Many bean varieties nodulate late and the nodules remain for a short period.

The technology of availing the bean Rhizobium inoculum to farmers is well known. The biofertiliser technology is presently accepted by farmers in countries where it is employed, as in Kenya and Rwanda. In Uganda, good information on exploitation of Rhizobium-bean symbiosis in the national cropping systems is needed. Therefore, in this paper a progress report is made on investigations in:

1. The importance of inoculating beans for its effects on

nodulation, nitrogen-fixation ability and subsequent grain yield.

2. The effect of different levels of nitrogen fertiliser on the nodulation, nitrogen fixation and yield of inoculated beans.
3. The effect of ammoniacal and nitrate nitrogen forms on the nodulation and nitrogen fixation and yield of inoculated beans.
4. The contribution of nitrogen fixation by beans on soil nitrogen balance.

Materials and Methods

The first of the bean field trials to be run for two years at Makerere University Farm, Kabanyolo was planted on 14 April 1987. Kabanyolo soil is ferrallitic, derived from argillaceous members of the Toro Systems of the Precambrian and is mapped under Buganda catena. Before planting, new land was opened and tractor ploughed. The land selected had not been grown with legumes for over five years and had never been grown to inoculated beans before. Its soil was poor in nitrogen, having 0.068% N and with a medium soil pH of 5.9, which were appropriate for successful Rhizobium-bean symbiosis. Fertility of the soil was boosted with a blanket application of single superphosphate, muriate of potash, sodium molybdate at 100kg P_2O_5, 60kg K_2O and 30kg sodium molybdate per hectare respectively. The fertilisers were hand broadcasted and worked into the soil before planting.

Treatments included uninoculated (I_0) and inoculated (I_1) interacting with nitrogen fertilisers applied at different levels, namely: 0, 20, 40 and 60 kg/ha N (N0, N1, N2 and N3 respectively). Two nitrogenous fertilisers were included viz: urea as ammoniacal form and nitrochalk as nitrate type. They were applied and worked into the soil on the planting day. Good quality, undressed bean variety K20 seeds were inoculated with commercially prepared inoculants obtained from Kenya. Inoculation was done by the pelleting method according to Vincent (1970).

Plots for uninoculated seed were planted first to eliminate contamination. Planting was done in plots of 4 m by 4 m at a spacing of 30 cm by 10 cm with two seeds per hill. A sample of inoculated seeds was taken and its viable rhizobia cells per seed estimated by dilution plate method (Vincent, 1970), giving 108 cells per seed. The germination, over 95%, was good. Diseases and pests were controlled using Dithane M-45 and Ambush sprayed to the crop using a knapsack sprayer. The crop was kept weed free.

At three and six weeks after planting (WAP), eight plants were carefully uprooted using a hoe. Their nodules were collected, washed, counted, dried and weighed then expressed as nodules per plant and weight per nodule which gave the nodulation of beans. Shoots were collected, oven-dried and weighed to give plant growth expressed in dry shoot weight per plant. As the work is continuing, the shoots will be ground and samples will be taken for nitrogen analysis to determine the nitrogen that was fixed. All the treatments were arranged in a factorial experimantal design of 2 x 2 x 8 replicated four times. The collected data was subjected to ANOVA analysis using a computer.

Results and Discussion

Nodulation

Table 1 shows means of number of nodules per plant. There is no significant difference between the effects of ammoniacal and nitrate nitrogen on means of nodule number per plant at 3 WAP or 6 WAP. However, it is clear that there is high significant difference between the means of nodules per plant 3 WAP and 6 WAP for the same treatment combination. Treatment combination of 40 kg/ha N and inoculation gave the highest mean nodule per plant, over double that of the control. The second was inoculation with no nitrogen application and the third, surprisingly, is the combination of highest level of nitrogen (60 kg/ha N) and inoculation.

Table 2 shows the weight per nodule. It is evident that there is not much difference between nodule weight for ammoniacal and nitrate nitrogen at each sampling time. There are distinct differences between the means of each treatment combination at 3 WAP and 6 WAP. This is mainly due to developmental process of the nodule; its mass increases with duration. Plant growth in terms of mean weight of dry shoot per plant is shown in Table 3. There is no evidence of significant differences between means of ammoniacal and nitrate nitrogen. At the same time there is not much difference in plant growth between different interactions and inoculation and nitrogen application levels, except that of 60 kg/ha N and inoculation which had the highest shoot weight per plant. Figure 1 shows the trends of means of nodule number per plant and weight per nodule. It shows clearly that with high number of nodules the nodule mass decreased. And it also shows that high nodule mass is associated with uninoculated plots. Therefore, the native rhizobia seem to form bigger though fewer nodules than the inoculum strains obtained from Kenya, which formed many nodules but with low nodule mass. Suggestions now are to get indigenous isolates. Nodule mass usually indicates the effectiveness of the Rhizobium-legume symbiosis.

Table 1. Effect of ammoniacal and nitrate nitrogen at different application levels with inoculation on mean number of nodules per plant at two sampling times.

Sampling time	Type of N-Fertiliser	Levels of N-application (N) x inoculation (I) N_0I_0	N_0I_1	N_1I_0	N_1I_1	N_2I_0	N_2I_1	N_3I_0	N_3I_1	Means
3 WAP	ammoniacal	5.75	5.50	3.00	4.75	6.25	9.75	4.25	5.25	5.56
	nitrate	2.75	9.25	4.25	5.25	2.50	7.00	1.75	10.75	5.44
6 WAP	ammoniacal	11.00	31.00	11.25	17.75	11.00	38.00	12.00	22.75	19.40
	nitrate	15.75	25.75	10.50	24.75	16.00	27.50	11.50	23.00	18.10
	Means	8.81	17.88	7.25	13.13	8.94	20.56	7.38	15.44	

Table 2. Effect of ammoniacal and nitrate nitrogen at different application levels with inoculation on mean weight per nodule at two sampling times (in mg).

Sampling time	Type of N-fertiliser	Levels of N-application (N) x inoculation (I) N_0I_0	N_0I_1	N_1I_0	N_1I_1	N_2I_0	N_2I_1	N_3I_0	N_3I_1	Means
3 WAP	ammoniacal	1.88	1.05	1.90	1.15	2.25	1.13	2.78	1.73	1.73
	nitrate	2.85	1.73	2.38	1.15	2.35	1.78	1.95	0.88	1.88
6 WAP	ammoniacal	3.20	3.65	3.00	2.38	3.25	2.75	2.77	1.80	2.85
	nitrate	3.03	2.95	4.33	2.45	4.20	2.78	4.53	3.25	3.44
	Means	2.74	2.34	2.90	1.78	3.01	2.11	3.01	1.91	

Table 3. Effect of ammoniacal and nitrate nitrogen at different application levels with inoculation on mean weight of dry shoot/plant (in g).

Sampling time	Type of N-fertiliser	Levels of N-application (N) x inoculation (I)								
		N_0I_0	N_0I_1	N_1I_0	N_1I_1	N_2I_0	N_2I_1	N_3I_0	N_3I_1	Means
3 WAP	ammoniacal	1.25	1.60	1.45	1.50	1.83	1.65	1.68	1.83	1.73
	nitrate	1.08	1.00	1.50	1.30	1.68	1.78	1.68	1.35	1.88
6 WAP	ammoniacal	5.83	6.20	5.83	5.93	8.33	7.33	8.38	9.05	2.85
	nitrate	4.45	4.85	5.15	6.45	6.30	7.10	5.70	6.33	3.44
	Means	3.15	3.41	3.48	3.79	4.53	4.46	4.36	4.64	

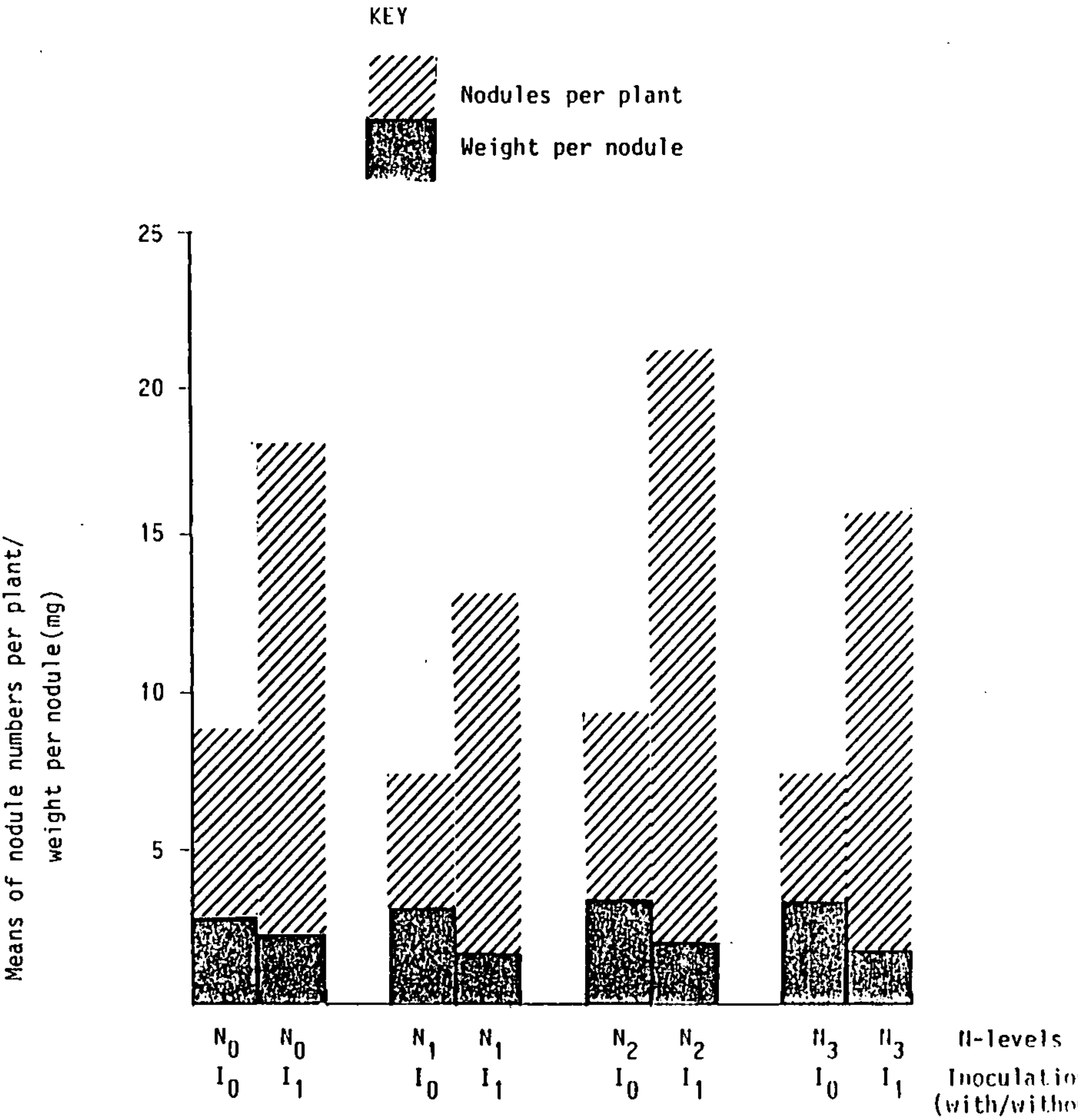

Figure 1. Effect of nitrogen application and inoculation on nodule number and weight per nodule.

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The Problem of Premature Pod Abscission in Common Beans

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Abstract

A study was carried out in the greenhouse on the post-flowering reproductive development of a determinate five-noded bean (*Phaseolus vulgaris*) cultivar, to determine patterns of flowering and reproductive abscission for individual nodes on the main stem. Individual flowers were tagged at anthesis and monitored through abscission or pod maturity. Date of flowering, pod setting and flower or pod abscission were recorded. Abscission was calculated on a per node basis. Number of mature pods/node, seeds/pod and weight/seed were recorded for each main stem node. Flower and pod production at different levels within the canopy were variable, the lowermost node producing more flowers and pods than any of the other nodes. Flower abscission was not found to be of significance under the conditions in which the experiment was conducted. Nearly every flower that opened developed into a pod, and for the whole plant, there was only 4% flower abscission. Pod abscission was found to be a more serious problem than flower shedding, the whole plant losing up to 65% of its pods. The flowers that opened earliest had a greater likelihood of producing pods that reached maturity. There were no marked differences in the average number of seeds/pod and weight/seed for the different nodes. The differences in seed yield between nodes were largely due to differences in pods/node.

Introduction

The common bean, *Phaseolus vulgaris*, is the most widely cultivated of the Phaseolus species, its production accounting for approximately 95% of the total *Phaseolus* production, the other three cultivated species, *P. lunatus*, *P. coccineus* and *P. acutifolius* accounting for less than 5% of total *Phaseolus* bean production (Laing *et al.*, 1984).

Bean yields are considerably lower than cereal crop yields. Whereas maize yields for example reach 10-12 t/ha (Allison, 1969; Harrison, 1970), bean average yields are usually less than 1.0 t/ha in most developing countries and less than 1.6 t/ha in most developed countries (Laing *et al.*), though yields of 2.19-4.12 t/ha have been recorded under experimental conditions (CIAT, 1978). Although insect pests (van Schoonhoven and Cardona, 1980) and diseases (Sanders and Schwartz, 1980) are reported to be major constraints to bean yields, the application of pesticides has still not made significant improvements to grain yields (Ojehomon, 1968). The bean plant produces an enormous number of flower buds, flowers, and ultimately pods, so that flower number is not a limiting factor to yield. One of the possible causes of low yields in this crop is abscission of flower buds, flowers and immature pods. Binkley (1932) reported a high negative correlation between yield per plant and percentage flower and pod abscission in *Phaseolus vulgaris*. Flower bud abscission has been estimated at 33% (Ojehomon, 1966), flower abscission at 52-71% depending on cultivar, (Subhadrabandhu *et al.*, 1978a) and the process of premature abscission of reproductive organs continues right into maturity (Hansen and Shibles, 1979). It seems clear therefore that beans shed most of their reproductive organs and this consequently limits the final seed yield. Thus, together with the other constraints to bean yields, the problem of premature shedding of fruits should receive attention. In this paper the patterns of flowering, pod setting and pod abscission are described for a five-node determinate variety of *Phaseolus vulgaris*.

Materials and Methods

Bean seeds of the determinate, bush cultivar No.344 were sown in a 1:1:1 soil, peat and sand mixture in 30 x 45 cm plastic trays and watered regularly. Eleven days after sowing, seedlings were selected for uniformity and transplanted into 15 cm pots containing a John Innes II soil mixture.

When flower buds started to appear, plants were again selected for uniformity. Twenty such plants were selected, but in the course of the experiment one plant was accidentally damaged and therefore excluded from further observation. The plants were grown in a heated glass-house with an automatic ventilation system, where maximum and minimum temperatures averaged 21.6^{o} and 19.8^{o}C respectively. When the first flowers opened on 50% of the plants (hereafter referred to as anthesis), the plants were inspected daily and flowers that opened each day were counted for each node and tagged with coloured alpha tags on which dates of flowering were indicated. To facilitate identification of individual nodes in the canopy, a different colour of tag was used to mark flowers for each individual node. The development and fate of each flower was monitored and the date of flower or pod abscission was recorded, making it possible to determine which flowers produced mature fruits and which dropped prematurely. Thus, for each flower, dates of flower opening, pod setting and flower or pod abscission were recorded.

Results

The uppermost node produced the first open flowers; 80% of its flowers opening within the first four days of flowering. Node II followed in having open flowers, 87% of its flowers opening within the first five days of flowering. Both nodes II and V had a short and highly concentrated flowering period, reaching a peak three days after anthesis for both nodes (Fig. 1). Flowering on nodes I, III and IV started 2-3 days after anthesis. These nodes had a longer and less concentrated flowering period of 15-17 days (Fig. 1). Node I produced more flowers than any of the remaining nodes, accounting for approximately 45% of total flower production (Table 1). Within each raceme on any particular node, flowering started on the lowermost triad and progressed acropetally.

There was very little flower abscission. On average, the whole plant shed only 4% of its flowers, abscission being highest on the lowermost node (Table 1). Thus, 96% of the flowers that opened developed into pods.

An open flower formed a visible pod 2-3 days after opening. Like flowering, pod setting started earlier on nodes V and II and was more concentrated in duration, attaining a peak 5-6 days after anthesis. Thus, 80% and 84% of the pods at nodes V and II respectively, were produced within the first four days of fruiting. The setting of pods at nodes I, III and IV followed the same pattern as flowering, being less concentrated in duration. Node I produced more pods than any of the other nodes (Table 1).

The onset of pod abscission was a general plant phenomenon, starting at about the same time for all nodes. The shedding of pods started fifteen days after anthesis and continued for three weeks, the duration being slightly longer for the lowermost node. The results show that the shedding of pods was more pronounced than flower abscission. Whereas flower abscission was only 4%, the whole plant shed 65% of its pods. Node I had the highest degree of pod abscission (74%) compared to 45% and 52% at nodes II and V respectively (Table 1). There was a positive ($r = 0.89$) and highly significant ($p \leq 0.01$) correlation between the magnitude of pod abscission and the number of flowers produced.

The yield profile of pods that were retained to maturity directly relates to the patterns of flowering. Almost all the pods that were retained to maturity were produced from flowers that opened within the first ten days of the 17-day flowering period. At maturity, a clear distinction was observed between fully developed seeded pods and those pods which, though retained to maturity, had undergone abortion during the course of pod filling. The former are hereafter referred to as harvestable and the latter as non-harvestable pods. A pod was regarded as harvestable if it contained at least one mature normal-sized seed. Of the pods that reached maturity, almost all the harvestable ones were derived from flowers that opened within the first five days of the flowering period. Flowers that opened after one week of flowering gave rise mostly to non-harvestable

Table 1. Summary of Results.

Character	Node I	Node II	Node III	Node IV	Node V	Whole plant
Average no. of flowers produced	13.37 ± 0.70	3.26 ± 0.19	4.63 ± 0.23	3.68 ± 0.31	5.10 ± 0.32	30.05 ± 0.92
Average no. of flower shed	0.58 ± 0.21	0.21 ± 0.10	0.11 ± 0.10	0.16 ± 0.10	0.16 ± 0.11	1.21 ± 0.20
Average no. of pods set	12.79 ± 0.69	3.03 ± 0.19	4.47 ± 0.34	3.47 ± 0.33	4.95 ± 0.29	28.74 ± 0.96
% of flowers developing into pods	95.70 ± 1.60	93.50 ± 2.80	96.50 ± 2.80	94.30 ± 2.80	97.10 ± 1.42	95.60 ± 2.30
Average no. of pods shed	9.47 ± 0.73	1.37 ± 0.22	2.84 ± 0.28	2.42 ± 0.29	2.58 ± 0.96	18.68 ± 0.96
% pod abscission	74.00 ± 3.26	44.90 ± 5.35	63.50 ± 4.59	69.70 ± 5.13	52.10 ± 4.75	64.90 ± 2.88
Average no. of pod retained to maturity	3.11 ± 0.28	1.68 ± 0.13	1.58 ± 0.14	1.00 ± 0.13	2.26 ± 0.20	9.63 ± 0.36
% of flowers giving rise to mature pods	23.30 ± 2.70	51.50 ± 4.20	34.10 ± 2.90	27.20 ± 3.90	44.30 ± 4.60	32.10 ± 1.63
Average no. of harvestable mature pods	2.00 ± 0.20	1.55 ± 0.14	1.16 ± 0.14	0.89 ± 0.11	2.16 ± 0.21	7.79 ± 0.33
Average no. of aborted (non-harvestable mature pods)	1.11 ± 0.22	0.11 ± 0.42	0.42 ± 0.14	0.11 ± 0.10	0.11 ± 0.10	1.84 ± 0.26
% of flowers that formed harvest-able mature pods	14.90 ± 1.60	48.50 ± 4.40	25.10 ± 3.40	24.20 ± 3.80	42.40 ± 4.60	25.90 ± 4.70
Average seed no. per pod	3.53 ± 0.18	3.36 ± 0.27	3.96 ± 0.22	3.40 ± 0.22	4.06 ± 0.10	3.66 ± 0.15
Average seed weight (mg)	73.60 ± 2.00	73.20 ± 1.60	73.10 ± 2.30	75.00 ± 1.90	75.60 ± 1.90	72.50 ± 1.30

pods. Nodes II and V had the highest retention of pods to maturity while node I had the lowest. Only 23% of the flowers produced at node I gave rise to pods that were retained to maturity, compared to 51% and 44% for nodes II and V respectively. Similarly, only 15% of the flowers produced at node I gave rise to harvestable pods compared to 48% and 42% for nodes II and V respectively. Considering the plant as a whole, only 32% of the flowers produced pods that reached maturity; 26% of the flowers gave rise to harvestable and 6% to non-harvestable pods.

There were no marked differences in the average number of seeds/pod and average weight/seed for the different nodes. The differences in seed yield between nodes were largely due to differences in pods/node.

Discussion

The results obtained on flower production are similar to those of Pechan and Webster (unpublished), who found that all flowers that were produced on greenhouse bean plants formed pods. Taken together, these observations suggest that most, if not all, of the flowers are fertilised and therefore the subsequent loss of pods is not related to failure of fertilisation. The results, however, are at variance with those of Subhadrabandhu *et al.* (1978a) which reported flower abscission values of 28-62% under greenhouse conditions, depending on cultivar. Subhadrabandhu *et al.* also observed a higher degree of flower abscission in the field than under greenhouse conditions which they attributed to the greater number of flowers produced by field grown plants, and also to greater variations in the environmental conditions such as moisture stress, heat, wind, pests and diseases. The degree of flower abscission (and possibly pod abscission as well) therefore seems to vary with cultivar and environmental conditions.

The results also reveal that the shedding of pods started at a time when the earlier fruiting nodes had attained peak pod production and the rest of the nodes were about to attain it (Fig. 2). It therefore seems likely that the onset of pod abscission is a response to competition arising from heavy demands imposed on the plant's resources. The fact that pod and flower abscission was least on the nodes which had a short and concentrated flowering period and greatest on the lowermost node with a long and less concentrated flowering period, may have significant practical implications in any effort towards overcoming abscission. Varieties that have a short and concentrated flowering period may be more desirable, as prolonged flowering places pods from late-opening flowers at a temporal disadvantage.

That node I showed the highest abscission of pods is similar to observations made in soybeans by Wiebold *et al.* (1981), who found that the percentage of flower and pod abscission increased with canopy depth. It has been reported that not only is irradiance reduced (Sakamoto and Shaw, 1967), but also light quality is altered (Singh *et al.*, 1968) as light reaches the bottom of the crop canopy. Assimilate production would therefore be reduced in the shaded areas lower in the canopy. Competition for light is therefore a major factor for the lower mainstem nodes, and improved factor light penetration may increase the supply of photosynthate to flowers and pods at these nodes. Whether cultivars with an erect and open leaf canopy to facilitate light penetration to lower canopy levels have lower pod abscission on the lowermost node remains to be established. In the meantime, smaller leaf size appears to be a desirable character because shading of lower leaves is reduced, and there is a greater ability for leaf orientation towards the vertical position during daylight hours (Adams, 1973). This enhances light penetration into the canopy, thus maintaining a positive net CO_2 exchange for all leaves.

Another factor that may be involved in causing much abscission at the lowermost node is the possible competition from subterranean organs (roots and nodules). Root nodules of *Phaseolus vulgaris* have been reported to contain considerable amounts of cytokinins (Puppo *et al*,. 1974) and since these substances are known to attract metabolites (Adedipe *et al.*, 1970), it seems likely that pods on the lowermost node compete with roots and nodules for assimilates. In the light of the interdependence that exists between nitrogen fixation and photosynthesis, more research is needed to clarify the relationship between nodule activity and pod abscission in beans.

Meanwhile, several challenges still remain open to breeders and physiologists. Beans (Subhadrabandhu *et al.*, 1978), like soybeans (van Schaik and Probst, 1958), have been reported to exhibit genotypic variation in flower and fruit abscission. There might be a possibility for exploitation of genotypic differences. The present work, like that of Van Schaik and Probst (1958) in soybeans, has shown a highly significant correlation between flower numbers and pod abscission. Van Schaik and Probst concluded that it would be difficult to incorporate high flower number and low abscission of pods into a single genotype since the heritability of flower number and abscission of pods was found to be high, being 76% and 59% respectively. This implies that selecting for cultivars with low abscission of pods would mean selecting for those that produce fewer flowers. Initially, there is a need to establish the physiological basis for genotypic variation in abscission losses and to determine whether it originates from the architecture of the plant, from total flower production or from levels of endogenous plant growth substances.

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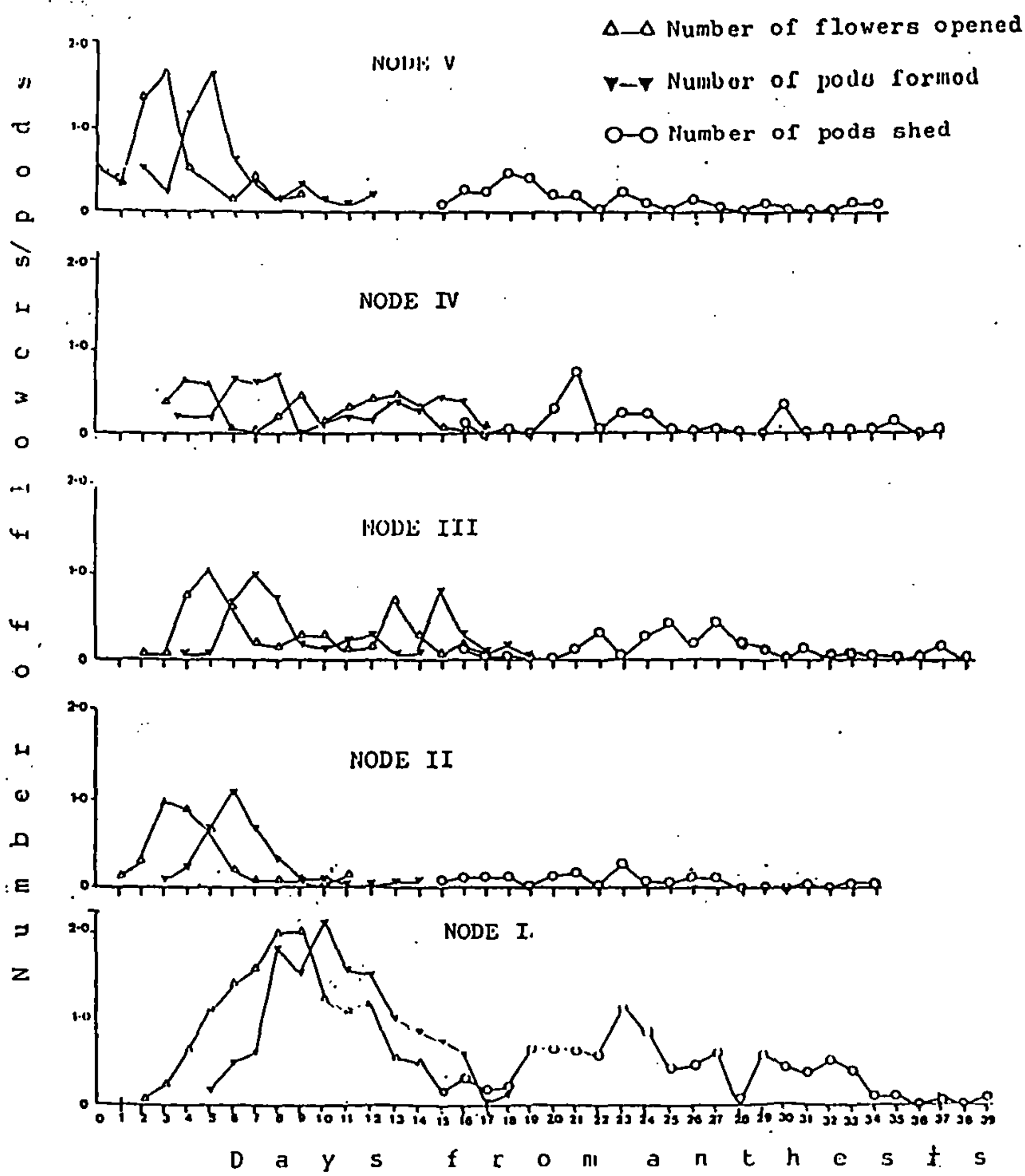

Fig. 1 . The mean number of flowers that opened, pods that were formed, and pods that abscised at each node on different days after anthesis.

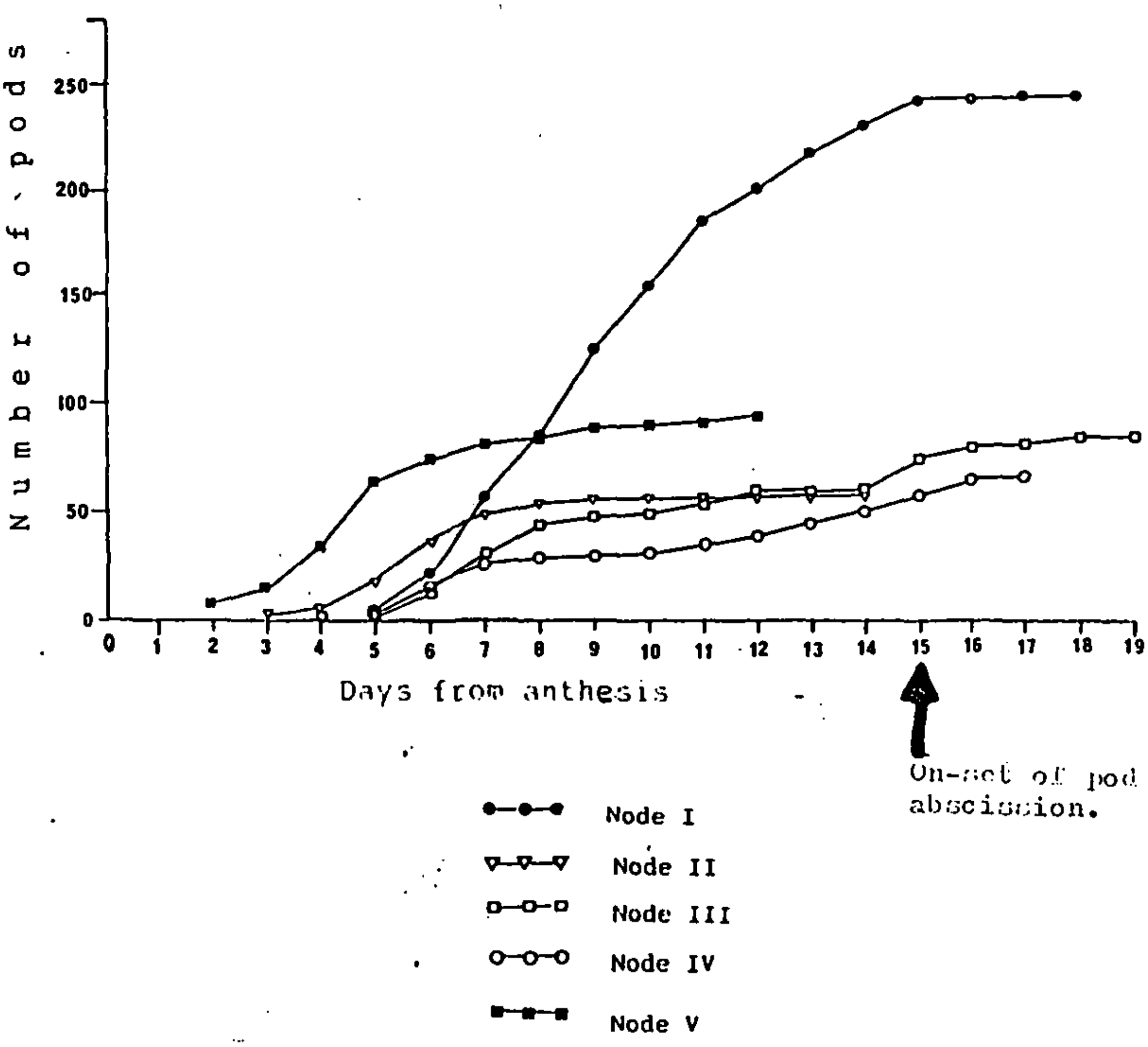

Fig. 2. The cumulative totals of pods at different nodes on different days after anthesis. Totals for 19 plants.

A Review of Bean Agronomy Research in Semi-Arid Regions of Ethiopia

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Introduction

Haricot bean (*Phaseolus vulgaris* L.) is one of the major pulse crops grown in the lowlands of Ethiopia. It is produced as a cash and food crop for local consumption. The important haricot bean producing regions in Ethiopia are Shoa, Sidamo, Harerghe and Wellega. A total of 19,600, 11,700 and 24,427 tonnes of dry bean seed were produced during 1981, 1982 and 1983, respectively.

The topography of most of the Ethiopian lowlands are suitable for bean production. However, the rainfall in these areas is usually low, erratic, with poor distribution and short in duration. High evapotranspiration rates and highly degraded soils with very low water retention capacity also contribute to the moisture stress problems. Therefore, the yield of haricot bean/unit area is usually low (about 600 kg/ha). The other important production constraints which limit bean yield in the semi-arid regions of Ethiopia are low soil fertility, weeds, high infestation of disease and pests, inappropriate timing in field activities (such as timely ploughing, planting, weeding, harvesting and other operations), lack of improved varieties etc.

In light of these constraints, a series of experiments was conducted to determine appropriate cultural practices, cropping systems, soil management techniques and other optimum field operations for higher and sustained yield increase in haricot bean production in low rainfall areas of Ethiopia.

Research Highlights

Seed-bed Preparation and Sowing Method Trials

In Ethiopia oxen-drawn implements are used for both primary and secondary tillage operations by peasant farmers. On the other hand, soil cultivation and seed-bed preparation on research centers and state farms are carried out with tractor-drawn implements, mostly using disc plough and harrow. Because of this discrepancy between the seed-bed preparation on the research centers and farmers' fields, some trials were carried out to compare different methods of seed-bed preparation and sowing using the *maresha*, ox-drawn wooden plough, during 1972-1976 at three sites. The first objective of the trials was to investigate different ways of row sowing using the *maresha* plough and compare the result with traditional broadcasting of the seed. The second objective was to investigate if the row sowing methods used would facilitate the weeding operation and thereby save labour.

In general, the yield levels obtained in these trials (oxen cultivation) were satisfactory compared to the other haricot bean trials in the same site and year which were hand sown in rows after tractor cultivation. The farmers practice (treatment 1) gave the highest yield in three trials (Koka, 1972 and 1976 and at Bako, 1975); it was only significantly (P = 0.05) inferior to any other treatment during 1976 at Bako (IAR, 1977). Treatments 4 and 5 gave the lowest yield. In treatment 4 the yields were probably low because of temporary water logging after heavy rain and by sowing in holes in the bottom of the furrow. The seed was placed in uncultivated hard soil and this probably restricted root development and uptake of nutrients. While in treatment 5 the seed was deeply buried and this could have delayed emergence and thus resulted in stand establishment problem. Therefore, from yield point of view, treatments 1,2,3 and 6 can be recommended.

Regarding reduction of weeding time by row sowing, the trials at Koka did not give any clear-cut answers. At Bako statistically significant differences in weeding time between treatments were obtained during 1975-76 season. Treatments 3, 4 and 6 are best in this respect. Hence, it can be concluded that good yields of haricot bean can be obtained using the traditional methods; that is, ploughing 2-3 times with *maresha* plough, broadcasting the seed and covering it with a subsequent ploughing. Some reduction in the time needed for weeding was achieved by row sowing.

Planting Date Trials

The amount of rainfall in the semi-arid regions is usually low, erratic, with poor distribution and short in duration. Planting dates should therefore be adjusted in such a way that critical crop growth stages coincide with optimum environmental conditions for crop growth and development.

In light of this, several experiments were conducted in the lowland areas of Ethiopia to determine the optimum planting date for haricot bean production.

The results obtained indicate that early sowing of haricot bean in the main rainy season gives the highest yield. The yield decline after the start of the rainy season was often larger than one percent/day delay in sowing. Results from a large number of cereal crops have given the same result (Kidane, 1983). The optimum planting date for haricot bean in the semi-arid regions would then be late June to early July. Analysis of meteorological data indicated that water stress toward the end of the rainy period was a main factor reducing yield for late sowing. It is also suggested that the flush in mineralisation of nitrogen which occurs when the dry soil is rewetted after the dry season at the start of the rains, is another factor contributing to the positive effect of early sowing (Ohlander, 1980). The early sown haricot bean may also have benefited from a longer growing period.

It was found that each day's delay in sowing after the first date caused 0.1 day earlier in flowering and 0.3 day earlier in ripening, on average. This shortening of the growth period may have several causes. Late sown beans will be exposed to the following changes in environmental factors when compared to early sown ones: increase in water stress and sunshine hours, reduction in air relative humidity, increase in maximum temperature at the end of the growth period. All these changes are likely to affect the plants in the same direction, towards faster development (Ohlander, 1980).

Plant Population Trials

The most common cause for low crop yield in the semi-arid tropics is poor seedling establishment. Within certain limits the relationship between soil moisture levels and plant density is such that the higher the available soil moisture, the higher the population density it can sustain. Soil moisture is often the limiting factor in the semi-arid regions, and measures should be taken to enable the crop to exploit as much moisture as possible. The first step is to establish the optimum plant population for an area. Thereafter maximum exploitations of available soil moisture by crop plant may be achieved by using appropriate spatial arrangements of plants.

Therefore, several experiments (about 28) were carried out to study the effect of plant population on growth and development of haricot beans during 1972/76 and 1984/85 seasons. In general, the results obtained indicate that there was a trend of yield increase with an increase of population densities (seed rates), but in most cases the difference in yield between the highest and lowest seed rates used has not been large and was statistically insignificant in most of the trials. The influence of inter-row spacing is less clear. However, there was an overall tendency for decreasing of the yield when inter-row spacing was increased. Theoretically, a uniform distribution of plants in the field should give the best results, but this can be difficult to arrange in practice, and the positive effect can easily be nullified by more difficult weed control and/or more damage to plants when weeding is done.

Considering all factors, a seed rate of 60-70 kg/ha and 40-60 cm inter-row spacing seems to be optimum for the semi-arid regions of Ethiopia. If good general husbandry is used (good seed-bed preparation, timely sowing etc.), the lower seed rate can be chosen. If any of the factors are less than optimum, higher seed rates should be used (Ohlander, 1980).

Fertiliser Trials

Soil fertility is one of the major crop production constraints in the lowland areas of Ethiopia. Soils are especially deficient in nitrogen and phosphorus. Therefore, a large number of trials were carried out to study the effect of nitrogen and phosphorus application in haricot bean yield.

The results indicated that significant seed yield increase was obtained with application of 40-70 kg/ha P2O5. The effect of nitrogen was much less marked as can be expected from a legume crop, but additions of 20-30 kg/ha gave yield increases in the trials (Nazreth, 1977).

Haricot bean is grown under a wide range of soil types and other environmental factors, thus generalised recommendations are difficult to make. The trial results indicate, however, that application of 20-30 kg/ha N and 40-60 kg/ha P2O5 is generally satisfactory. The most suitable fertiliser will then be diamonium phosphate (DAP) containing 18 kg N and 46 kg P2O5 per quintal (IAR, 1977).

Intercropping Trials

In the semi-arid regions haricot bean is traditionally intercropped with cereals, usually sorghum and maize. Some intercropping studies at ICRISAT indicated that under severe water stress conditions intercrop yields decrease less rapidly than sole crop yield (Wiley, 1979). Some preliminary experiments were therefore conducted to study the influence of cowpea, haricot bean and mungbean with association seed yield of maize and sorghum. Maize-bean mixtures were favourable and significant on the component yield of maize. Similar results were obtained with sorghum. Thus, a higher Land Equivalent Ratio (LER) was obtained when haricot bean was intercropped with both maize and sorghum.

Thereafter, further experiments were carried out to study the effect of population arrangement at a given substitution on the relative yield of sorghum and haricot bean when intercropped as compared to sole crop yields; 2/3 sorghum and 1/3 haricot bean planting ratios have higher LER and are recommended for the semi-arid regions of Ethiopia.

Harvesting Trials

In Ethiopia harvesting of haricot bean is normally done when most of the pods and seeds have dried. At this stage the pods are brownish and have a brittle texture. This usually leads to shattering and consequently loss of yield.

Therefore, to study the effect of comparatively early harvesting on bean yield and to observe possible change in shattering losses when harvesting is delayed, harvesting stage trials were carried out at four locations during 1972 and 1974-75. Generally, the experimental results indicated that there was no significant difference in harvesting by pulling the plants and stooking them in the field for final drying. This can be started when 50% of the pods have yellowed, or delayed until about ten days after all seeds have hardened, without significant change in yield. This gives a timespan from first to last harvest of about 30 days.

Future Research Directions

1. Continue the study on developing soil management practices for soil moisture conservation to enhance haricot bean production under dry land farming conditions.

2. Continue to assist breeders in the screening of drought tolerant/resistant haricot beans cultivars.

3. Study the conditions necessary for satisfactory seedling establishment (optimum population densities, planting date, depth etc. on the basis of soil moisture conditions and rainfall analysis).

4. Continue to develop agronomic practices and packages following the release of the new bean cultivars.

5. Classify the region into recommendation domains and conduct research accordingly.

6. Conduct agronomic studies on farmers' fields after obtaining detailed information from research centres.

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Appendix

Trial treatments and cultural practices used

A. Seed-bed preparation and sowing methods trials

Treatments:

1. Seed was broadcast and covered by one ploughing (Farmers' common practice).

2. The land was ridged with the plough, ridges at 45 cm distance, then seed was broadcast and covered by splitting the ridges with the plough.

3. The land was ridged as in treatment 2, the seed sown on the bottom of the furrows, 7 cm between seeds, and covered by splitting the ridges. Ridges were cross-tied every 5 m.

4. The land was ridged as in 2, the seed sown in the bottom of the furrows with the aid of a planting stick, 7 cm between seeds. Ridges were cross-tied every 5 m.

5. A furrow made with the plough, seed sown in the furrow at about 7 cm distance between seeds and covered by making a second furrow close to the first. A third furrow was made close to the second, seed sown in that furrow and covered with a fourth, etc.

6. Seed sown by hand in rows 45 cm apart and with 7 cm distance in the rows.

Cultural practices:
Variety: Mexican 142
Seed rate: 60 kg/ha Fertiliser 27 kg N and 59 kg P_2O_5

All other cultural practices recommended for bean production were used.

B. Harvesting stage trials

1. Harvesting was done by pulling the plants and stooking them in the plot for drying when 50% of the pods were yellow (the rest of the pods still green).

2. Harvesting was done when 75% of the pods were yellow.

3. Harvesting was done when all pods were yellow.

4. Harvesting was done when all seeds had hardened.

5. Harvesting 10 days after stage 4.

Effect of Weed Competition on the Yield of Beans at Melkassa, Ethiopia

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Abstract

A handweeding treatment to find out the critical period of competition between haricot bean (*Phaseolus vulgaris*) and weeds and to estimate the yield loss due to weeds was carried out on heavy and light soils at Melkassa, Nazreth for three consecutive years (1980-82). Six handweedings at different phenological stages of the crop development and an unweeded (check) were laid out in a randomised complete block design with four replications. Out of tested treatments, early growing stage of the crop (10-15 days after emergence) was found to be the critical time of competition. There was variation among weed species distribution between two soil types. The weed infestation being more on light soil than on heavy soil, the average yield levels in the unweeded control plots were reduced to 64% and 37%, respectively. Weeding a few weeks before harvesting was not much better than not weeding at all.

Introduction

Haricot bean in the Rift Valley of Ethiopia (the region served by Melkassa Research Centre) is produced more for export purpose than for home consumption. The production of this crop is limited by many factors. Among these, weeds are the most important one. They deprive the crop of water, minerals, nutrients and light which would otherwise be available to it. Weeds are often faster growing and more efficient at utilising nutrients than the crop and therefore have a distinct competitive advantage. Moreover, they serve as hosts for many other pests such as insects, nematodes, fungi, bacteria and viruses. They also interfere with harvesting and other farm operations. The extent to which yield is depressed by weed competition varies greatly. It depends upon the adequacy of resources available but mainly on the competitive ability of the crop relative to that of the weed population (Roberts, 1982).

All the time and money spent by geneticists, soil scientists, entomologists and plant pathologists in improving cultivated plants or raising their productivity can be wasted unless the weeds are controlled in the right manner and at the right time (Nieto *et al.*, 1971). As most grain legumes grow fairly slowly at first, they are most vulnerable to weed competition in the first quarter or third of their life. After this they can generally shade out most weeds. Weed competition commences at about two weeks. It is thus in the first few weeks that the greatest damage is done by weeds. It has been shown for all tropical grain legumes that keeping the crop weed-free for something like four to six weeks produces yields only a little less than keeping it weed-free throughout its whole life. The timing of weed control is thus very important (Centre for Overseas Pest Research, 1981).

The intensity of competition varies at different stages of the development of the crop. There are periods when weeds must be removed and other periods when weeds may be allowed to grow because they do not cause the slightest harm to the crop (Nieto *et al.*, 1971). Knowledge about this critical period will enable the exploitation of the best time of controlling weeds either by hand weeding or by other means. This will again give information on the yield losses which in turn help to assess the economic feasibility of introducing alternative methods of weed control.

Materials and Methods

The experiment was conducted at Melkassa on heavy and light soils for three years (1980-1982) during wet seasons, using six frequencies of hand weeding and an unweeded (check) treatment. This includes:

1. Check (unweeded)
2. Weeded as needed for the whole growing season
3. Weeded during early season 10-15 days after emergence
4. Weeded during mid season 30-35 days after emergence
5. Weeded during early and mid season
6. Weeded during late season on the 60th day after emergence
7. Weeded during mid and late season

Such set-up of treatments has been employed by Dawson and Holstun (1971), Maini *et al.*, (1968) and Nieto *et al.*, (1971). The plots were each 24 m2 arranged in a randomised complete block design with four replications. The haricot bean variety used being Mexican 142, the seeds were sown by hand in rows of 10cm between plants and 40 cm between rows. Two seeds per hole were sown and eleven days later thinned to seedling. Weedings were performed both by hand-pulling and hoeing. In order to estimate the cost of weeding, the time taken to weed each plot was recorded. Stand count was taken two times, at 25 days after emergence and just before harvesting. Individual weed count was taken by throwing a quadrat 25 cm x 25 cm four times randomly in each plot. Leaving one row on each side and about 5 cm at the top and bottom of each plot as border rows, eight rows were harvested for seed yield. The percent yield loss was estimated by comparing the highest yielding treatment with other treatments.

Results and Discussions

The most important weed species recorded on the heavy soil were *Digitaria abyssinica* (= *D. scalarum*), *Cyperus rotundus*, *Flaveria trinervia* and *Launea cornata*. Although some of these were also observed in the light soil, the more frequent ones were: *Amaranthus hybridus*, *Datura stramonium*, *Sorghum* sp. (wild sorghum), *Eragrostis multiformis* and *Commelina benghalensis*. The relative composition of weed flora on heavy soil was 55% broadleaf and 45% grasses, and on light soil the broadleafed weeds were less abundant (46%) than the grasses (54%).

Significant yield reduction (P=0.05) was obtained from unweeded check, late season, and mid plus late season treatments as compared with the treatment weeded during early plus mid season. The treatment which was weeded when the crop was only about 10cm high and repeated in mid-season, that is, when very few flowers started to appear, gave the highest yield of 2,482 kg/ha and 1,946 kg/ha from heavy and light soil respectively. The frequent-weeding treatment, which was weeded three times, gave yields of 2,247 kg/ha on heavy soil and 1,742 kg/ha on light soil. This yield reduction in the second treatment could be due to the flower shedding that took place while weeding was done during late season. The damage was very high since the crops were interwoven with one another.

The yield obtained from all treatments on heavy soil was greater than the yield obtained from similar treatments on light soil and the yield loss incurred due to weeds was also less on heavy soil. These could possibly be attributed to the presence of high organic matter and the higher retentive capacity of the heavy soil. Another possibility may be due to differences in the growth pattern and composition of the weed species found in the two sites. For example, *Datura stramonium* grew very vigorously and was very common on light soil. This weed sp. forms a tall canopy and this could compete with the crop more than the smaller weed species. Moreover, due to the abundance and high competitive ability of weeds in the check and late-weeded plots especially on light soil, the crop was not in a position to have as many branches and pods as it could. But, as regards to plant population, there were no significant differences between treatments.

As the three years' results indicated, significant yield differences obtained in the best yielding treatment was due to the early season weeding. Hence, the critical time of weed competition that affected the yield of haricot bean or the right time of weeding in haricot bean is during its early growing season (10-15 days after emergence); the yield loss incurred due to weed competition was estimated to be 37% and 64% on heavy and light soil respectively. This result agrees with that mentioned by Centre for Overseas Pest Research (1981). Critical period is

Table 1. Effect of different weeding times on the yield of haricot bean at Melkassa (heavy soil) 1980-82.

Treatments	1980	1981	1982	Mean	Estimated yield loss %
1 Unweeded (check)	10.85	13.08	23.25	15.73	37
2 Weeded as needed for the whole growing season	16.19	24.90	26.31	22.47	9
3 Weeded during early season (10-15 DAE)	15.55	22.84	28.13	22.17	11
4 Weeded during mid season (30-35 DAE)	13.34	22.99	29.38	21.90	12
5 Weeded twice during early and mid season	19.14	25.64	29.69	24.82	0
6 Weeded during late season (60 DAE)	12.94	14.49	23.44	16.96	32
7 Weeded twice during mid and late season	14.62	19.33	26.75	20.23	18
LSD 5%	2.89	2.29	4.74	3.46	

Table 2. Effect of different weeding times on the yield of haricot bean at Melkassa (light soil) 1980-82

Treatment	Yield kg/ha				Estimated yield loss %
	1980	1981	1982	Mean	
1 Unweeded (check)	3.42	7.13	10.26	6.94	64
2 Weeded as needed for the whole growing season	12.13	24.72	15.42	17.42	10
3 Weeded during early season (10-15 DAE)	9.88	21.92	15.36	15.72	19
4 Weeded during mid season (30-35 DAE)	7.19	18.67	17.19	14.35	26
5 Weeded twice during early and mid season	13.45	25.41	19.53	19.46	0
6 Weeded during late season (60 DAE)	5.38	8.30	10.83	8.17	58
7 Weeded twice during mid and late season	9.02	12.76	15.99	12.59	35
LSD 5%	4.72	2.46	4.17	6.19	

Table 3. Labour intensity and cost of handweeding at different times in haricot bean at Melkassa

Treatments	Frequency of weeding	Heavy soil		Light soil	
		Time Mandays/ha	Cost Birr/ha	Time Mandays/ha	Cost Birr/ha
1 Unweeded (check)	-	-	-	-	-
2 Weeded as needed for	3	127	247.65	86	167.70
3 Weeded during early season (10-15 DAE)	1	46	89.70	49	95.55
4 Weeded during mid season (30-35 DAE)	1	71	138.45	56	109.20
5 Weeded during early and mid season	2	76	148.20	59	115.05
6 Weeded during late season (60 DAE)	1	86	167.70	64	124.80
7 Weeded during mid and late season	2	113	220.35	92	179.40

* Labour cost = Birr 1.95/day (US$ 0.94)

Table 4. Effect of weeding on weeds, an average of three years' data at Melkassa (heavy soil), in numbers/m .

Treatments	Narrow leaved		Broad leaved weeds					
	Digitaria scalarum	Cyperus spp.	Flaveria trinervia	Launea cornuta	Tagetes minuta	Commelina benghalensis	Bidens pilosa	Others
1 Unweeded (check)	109	66	43	23	47	30	22	67
2 Weeded as needed	67	85	22	40	14	1	6	46
3 Weeded during early season (10-15 DAE)	100	58	45	35	25	7	7	74
4 Weeded during mid season (30-35 DAE)	83	84	61	25	29	11	6	76
5 Weeded during early-mid season	90	79	77	31	31	12	4	75
6 Weeded during late season (60 DAE)	97	54	49	22	27	39	11	64
7 Weeded during mid and late season	105	73	31	31	40	18	20	43
% of total weed population	25.7	19.7	12.9	8.2	8.4	4.7	3.0	17.5

Table 5. Effect of weeding on weeds, an average of three years' data at Melkassa (light soil), in numbers/m

Treatments	Narrow leaved			Broad leaved weeds				
	Sorghum spp.	Eragrostis maltiformis	Other grass weeds	Amaranthus hybridus	Galinsoga parviflora	Datura stramonim	Commelina benghalensis	Others
1 Unweeded (check)	122	32	8	24	14	22	57	15
2 Weeded as needed	101	23	12	24	16	2	28	19
3 Weeded during early season (10-15 DAE)	111	26	2	21	21	12	29	21
4 Weeded during mid season (30-35 DAE)	123	29	3	32	6	15	32	17
5 Weeded during early and mid season	119	39	2	27	23	6	15	13
6 Weeded during late season (60 DAE)	55	60	8	53	26	13	62	21
7 Weeded during mid and late season	40	24	3	39	9	13	25	19
% of total weed population	38.7	13.4	2.2	12.7	6.6	4.8	14.3	7.2

the maximum period when weeds can be tolerated without affecting final crop yield or the point after which weed growth does affect final yield (Zimdhal, 1980).

As the result showed, it was possible to get reasonable yields even by weeding once during early season, rather than weeding twice early + mid, mid plus late, late and the whole growing season. But growers often assume that removing weed competition any time during the growing season solves the problem. However, time of removal is as important as removal itself. Weeding without knowing the critical period is simply wastage of labour, time and money. If we take the heavy soil, late weeding treatment costs Birr 167.70 (1 Ethiopian Birr = US$0.49) which is almost double that of early growing season which costs Birr 89.70. The same is true for the whole growing season weeded treatment which costs Birr 247.65 without significant yield differences compared to early growing season. When weeding is carried out late in the season, weeds are vigorous and well established so that it is difficult to weed and takes more time as well as labour. In addition to this, when weeding is carried out during late season the crop is easily damaged mechanically.

Conclusions and Recommendations

Most farmers are producing haricot bean in the Rift Valley of Ethiopia without weeding, as shown by a survey conducted at Nazreth in 1986. Even if about 70% of farmers producing haricot bean believe they can obtain better yield by weeding, they do not do so due to shortage of labour. Time of weeding haricot bean overlaps with planting of teff and weeding maize. Therefore, most of the farmers give priorities in labour allocation for maize and teff. After planting and weeding these crops the farmers could have weeded haricot bean, but at this time the crop has already flowered and therefore farmers are forced not to weed. Our experimental result showed that weeding haricot bean late in the growing season is not economical due to mechanical damage on the crop.

Farmers also are aware of this condition and as a result they avoid late season weeding of the crop. However, to control weeds farmers use high seed rate and crop rotation as a strategy. As our experiment result indicated, 37%-64% yield loss was observed by leaving haricot bean unweeded, which is beyond the economic treshold level. Therefore, in order to improve the production of this crop, it is better to weed and cultivate at least once during its early growing season (10-15 days after emergence). Moreover, to make this recommendation practical for resource-poor farmers it is worthwhile searching for technologies that will either save labour or provide chemical control methods. Bean research at Melkassa has been widened to include herbicides and the use of new varieties with competitive growth habits.

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Weed Control in Beans in Northern Tanzania

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Abstract

Field experiments conducted at Lambo, Hai District, Kilimanjaro, Tanzania during 1985 and 1986 showed that pre-emergence application of Galex (metolachlor + metobromuron) and Dual 960 (metolachlor) in beans gave satisfactory weed control. Post emergence Furore and Fusilade gave good control of grass weeds. Handweeding at 14 and 35 days after planting and a combination of herbicide treatment followed by one handweeding at 35 days after planting gave season-long control of weeds and significantly higher bean yields.

Introduction

The dry bean (*Phaseolus vulgaris* L.) is an important supplier of protein to the people in Tanzania. It is mainly grown in the high altitude areas between 900 m and 2100 m (Acland, 1971). Comparative data (Anon, 1985) from three districts have shown that while maize, the major staple food, provides about 70% of the calories consumed by some families in Arusha Region, beans provide between 12 and 16%.

The crop is grown under rainfed conditions and weed growth is always abundant. To keep them in check two handhoeings are necessary. The critical period for weed competition in beans is during the first 30 days of their 100-135 days growth cycle (Nieto *et al.*, 1968). However labour shortages due to coffee harvesting during the critical weeding period for beans, together with the wet field conditions caused by frequent rains, make handweeding both difficult and expensive. The use of herbicides either alone or in combination with other weed control practices appears to have potential as a method of control.

Little information is available on the use of herbicides for the control of weeds in beans in Tanzania. Research data are also lacking on the relative benefits of handweeding, pre-emergent herbicide application and post-emergent herbicide treatments in reducing interference from weeds. Comparisons of pre-em/post-em applications of herbicides combined with row cultivation and overall herbicide applications also require further investigations so as to identify the most economical and effective weed management system.

Experiments reported in this paper were designed to provide part of such information. Weed flora in the experimental area and those considered of economic importance included: *Oxygonum sinuatum, Nicandra physalodes, Argemone mexicana, Sonchus* spp., *Ocimum canum, Commelina* spp., *Richardia scabra, Digitaria* spp., *Panicum* spp., *Setaria* spp. and *Sorghum verticilliflorum.*

Materials and Methods

The investigations were conducted at Lambo, Hai District, Kilimanjaro Region, Tanzania during 1985 and 1986. The soils are eutric nitosols of pH 6.0 (FAO classification). The experimental design in both years was a randomised block with four replications. Each treatment plot measured 8 rows x 50 cm x 8 m long. Data was taken from a net area of 5 rows x 50 cm x 6 m length. Beans (cv Canadian Wonder) were planted at the onset of rains at a spacing of 10 cm between plants. All treatments were fertilised with 30 kg/ha N and 60 kg/ha P2O5 at planting. The plots were sprayed with endosulfan for insect control.

Weed control treatments are given in Table 1, and additional information on herbicide formulations are given in Appendix 1. All herbicide applications were made at the rate of 300 l of spray mixture per ha.

The pre-emergence application of herbicides was carried out soon after planting. The post-emergence treatments were carried out when the second trifoliolate leaf had fully expended. For the weed-free check, weeding started 14 days after planting and continued at weekly intervals until beans had reached their physiological maturity.

Weed cover rating was done twice (4 and 8 weeks after planting). The rating scale was 1-10; the unweeded control plot was given a score of 10, while 1 meant total weed kill. Mean grain yield of clean dry seeds for each treatment was recorded.

Results

A summary of results is presented in Tables 1-3.

Effect on Weeds

Among the treatments Fusilade and Furore were active against grasses and showed extreme selectivity within the bean crop. Galex gave excellent control of both grasses and broad leaved weeds in 1985. Performance was less satisfactory in 1986. Basagran applied as post-em and Dual 960 as pre-em gave satisfactory activity against broad leaved weeds.

Table 1. Effect of treatments on weed cover and grain yield, 1985

Treat No.	Treatment	Rate (l product/ha)	Mean weed cover rating (4 weeks): Grasses	Mean weed cover rating (4 weeks): broad leaved	Mean weed cover rating (8 weeks): Grasses	Mean weed cover rating (8 weeks): broad leaved	Mean weed cover rating (8 weeks): Overall	Grain yield kg/ha
1	Furore	1.0	1.00c	8.00a	1.00b	9.25a	8.37b	566c
2	Fusilade	2.0	1.00c	8.62a	1.00b	9.25a	8.87ab	451c
3	Galex	5.0	1.12c	4.37c	1.25b	2.00c	2.00d	1272b
4	Basagran	3.0	3.50b	6.12b	1.75b	4.25b	3.87c	1297b
5	Handweeding 14+35 DAP	-	1.37c	1.50d	1.37b	1.50c	1.62d	1548a
6	Weed free check	-	1.00c	1.00d	1.00b	1.00c	1.00d	1396b
7	Control (untreated)	-	10.00a	10.00a	10.00a	10.00a	10.00a	374c
	S.e. of differences		0.41	0.42	0.43	0.38	0.57	200
	LSD (P-0.05)		0.88	0.88	0.90	0.79	1.19	125
	CV		24.9	10.8	26.0	10.1	15.9	28.7

a - d. Means bearing the same letter are not significantly different at the 5 percent level of probability, as assessed by Duncan's multiple range test.

Table 2. Effect of treatments on weed cover and grain yield 1986.

Treatment	Rate l product/ha	Mean weed cover rating (4 weeks): Grasses	Mean weed cover rating (4 weeks): broad leaved	Mean weed cover rating (4 weeks): Overall	Mean weed cover rating (8 weeks): Grasses	Mean weed cover rating (8 weeks): broad leaved	Mean weed cover rating (8 weeks): Overall	Grain yield kg/ha	Seed quality
Furore + 1 handweeding (at 35 DAP)	1.0	1.2c	8.6b	8.7ab	1.2de	3.0d	2.7cd	1043ab	3.0
Fusilade + 1 handweeding (at 35 DAP)	2.0	1.0c	4.6c	4.8c	1.2de	2.7d	3.0c	1222a	3.5
Galex	5.0	1.5c	3.0de	3.2cde	1.7cde	4.7c	4.7c	490c	3.5
Furore	1.0	1.0c	7.8b	7.3b	1.2de	8.7b	8.7a	72	3.0
Fusilade	2.0	1.0c	8.0b	8.0b	1.5de	9.0a	9.0a	105d	3.2
Metolachlor (Dual 960)	2.0	2.1bc	3.3cd	4.3cd	3.7c	5.0c	6.5b	421c	2.7
Handweeding at 14 DAP + Basagran at 35 DAP	3.0	1.6c	2.2ef	2.2ef	3.2cd	2.0d	3.2c	812b	3.2
Handweeding at 14 & 35 DAP	-	1.5c	1.5f	1.7f	2.2cde	1.5d	2.2d	1161a	3.2
Metolachlor + 1 handweeding	2.0	1.7bc	4.8c	5.2c	1.2de	1.7d	1.7d	1041ab	1.7
Weed free check	-	1.0e	1.0f	1.0f	1.0e	1.0de	1.0d	1005ab	2.5
Basagran	3.0	3.5b	4.0cd	5.2c	6.0b	3.0d	6.5b	519c	3.5
Control unweeded	-	7.5a	10.0a	10.0a	10.0a	10.0a	10.0a	83d	3.7
Mean		2.1	5.0	5.2	2.8	4.3	4.9	664	3.1
S. e. of differences		0.9	0.6	0.6	1.0	0.8	0.9	116	0.5
LSD (P = 0.05)		1.8	1.3	1.3	2.1	1.7	1.9	237	NS
CV %			18.9	17.6		27.4	27.6	24.9	20.0

a-f Means bearing the same letter are not significantly different (P = 0.05) by Duncan's multiple range test.

Table 3. Effects of treatment upon mean disease rating in bean crop.

Treatment	Rate kg or l product/ha	1985 (Rating scale 1 - 5)					1986 (Rating scale 1 - 5)		
		Anthracnose	White mold	Halo blight	Rust	ALS	Anthranose	White mold	ALS
Furore + 1 handweeding		-	-	-	-	-	3.5	4.5	3.2
Fusilade + 1 handweeding		-	-	-	-	-	4.0	3.5	3.2
Galex		3.62	4.50	3.37	1.87	1.0	3.5	4.75	3.5
Furore		3.37	3.62	1.0	1.87	1.0	3.5	5.0	3.5
Fusilade		3.25	4.12	1.12	1.62	1.0	3.5	4.7	3.0
Metolachlor (Dual 960)		-	-	-	-	-	4.0	4.5	3.7
Handweeding + Basagran		-	-	-	-	-	4.0	4.2	3.5
Handweeding at 14 + 35 DAP		3.37	3.25	3.12	1.25	1.0	3.7	4.2	2.7
Metolachlor + handweeding		-	-	-	-	-	4.0	4.2	3.2
Weed free check		3.50	3.25	3.25	1.62	1.0	3.5	4.2	3.2
Basagran		3.00	4.12	2.50	1.50	1.0	3.5	4.0	3.0
Control unweeded		3.50	3.62	1.62	1.12	1.0	4.2	4.7	3.7
S. e. of differences		0.37	0.46	0.42	NAS	NAS	0.31	0.40	0.3
LSD (P = 0.05)		NS	0.96	0.88			NS	NS	NS

ALS - Angular Leaf Spot
DAP - Days After Planting
NAS - Not Analysed Statistically

Effect on Yield

Treatments which provided good control of weeds increased yield significantly. Two handweedings (at 14 & 35 DAP) gave the maximum yield. Next in performance were Galex, Dual 960 and Basagran applied alone. Performance of Furore and Fusilade applied alone was poor, giving yields which were not significantly different from the unweeded control.

Other Effects and Observations

Slight crop injury was noted with Basagran; full recovery to normal growth was observed after a few days. *Ocimum canum, Nicandra physalodes* and *Sonchus* spp. were host plants to the white mold (*Sclerotinia sclerotiorum*) pathogen. The considerable intensity of diseases might have influenced the yields. Both anthracnose (*Colletotrichum lindemuthianum*) and white mold (*Sclerotinia sclerotiorum*) were severe in the two years.

Discussion

The studies indicate that *Phaseolus vulgaris* L. is a poor competitor with weeds during the first 5 weeks of its growth. Results (Tables 1 & 2) show that keeping the plots weed-free for only the first 2 weeks is not enough. It also appears that there is no advantage in keeping the bean field weed-free longer than the first 5 weeks. Findings suggest that the critical period for weed competition for the bean crop is within the first 35 days of their life cycle. Similar results were obtained by Kasasian and Seeyave (1968). Although Galex, Dual 960 and Basagran promised improved weed control, yields from these treatments were surprisingly low in 1986. This may possibly have been due to their short residual effect, allowing for reinfestation by weeds.

It seems that supplimenting Fusilade, Furore, Dual 960 and Basagran by one handweeding can keep the crop free of weeds until harvest. The application of these herbicides may reduce the number of weedings and delay the time at which weeding becomes necessary. The present intensification and diversification of cropping, shortage of labour and high wages may justify future use of these herbicides in this crop. Future studies will examine the economic aspect of herbicide use in northern Tanzania. The overall results in these experiments suggest that:

1. Two handweedings can give excellent control of weeds and increased yield. However, both annual and perennial weeds should be removed completely and timely.

2. A combination of either Furore, Fusilade or Dual 960 with one handweeding during the first 35 days of growth cycle of the bean crop can give effective weed control in dry beans.

3. Fusilade and Furore applied alone can be used safely to control grassy weeds in beans. The herbicides might be potentially useful where grasses are the most troublesome weeds.

4. It is not enough to keep the bean field weed-free for the first 2 weeks only, and there is no advantage in keeping the field weed-free longer than the first 5 weeks.

5. It is evident that optimum yields were obtained by keeping the ground weed-free during the first 5 weeks.

Further Research Needs

No doubt herbicides can be extremely effective and permit greater crop production than hitherto. However, considering herbicide use and weed research in Tanzania, it must be admitted that little is known about the effect of herbicides on the nutritive value of the various cultivars of beans (Saghir and Bhatti, 1970). More research is needed also on weed ecology and on the side effects of herbicides.

Large areas of land in Tanzania are farmed in small units with minimum mechanisation and technological improvement. Weed control is largely done by hand. Losses incurred are considered indirect because the need for land preparation and weeding limits the area cultivated and delays the planting of most crops. Attempts should therefore be made to consider the losses in beans due to weeds.

Acknowledgement

The author would like to acknowledge the help of the colleagues in the Food Crops Department for their continued cooperation in carrying out the experiments. My sincere thanks are due to Joseph Matata for his constant assistance.

References

Kasasian, L. and Seeyave, J. 1969. Critical periods of weed competition. PANS 15: 208-212.

Nieto, J.H., Brondo, M.A. and Gonzalez, J.T. 1968. Critical periods of the crop growth cycles for competition from weeds. PANS (C) 14: 159-166.

Appendix 1 : Herbicides used in the treatments

Common name	Trade name	Formulation	Manufacturer/ Distributor
fenoxaprop - ethyl	Furore	9 EC 90 g fenoxaprop-ethyl per litre	Hoechst
metolachlor	Dual	960 EC 960 g metolachlor/litre	Ciba - Geigy
fluazifop	Fusilade	125 g fluazifop-p-butyl/litre	Twiga Chemicals
metolachlor + metobromuron	Galex	500 EC 250 g metobromuron 250 g metolachlor/litre	Ciba - Geigy
bentazon	Basagran	Aqueous solution 480 g bentazon/litre	BASF

SUMMARY OF DISCUSSION

Varieties that exhibit delayed flowering may fix more nitrogen, but as a breeding strategy this could be in conflict with the need for early maturity for drought avoidance (as in Ethiopia).

In evaluating rhizobial strains for inoculation, evidence of yield gain in the beans is important. Also, care should be taken with introduced strains, which could be more competitive than locals without being more effective in fixation. Rhizobium inoculum is available commercially from the University of Nairobi, and is based on local strains.

Some bean varieties are influenced by the differences between short and main rainy seasons. Drought is often a cause of this genotype x environment interaction.

If an acceptable row planter can be developed, the problem of poor weed control in beans in parts of Ethiopia might be tackled through the introduction of beans into maize crops. Economic analyses of labour use (e.g. hand weeding treatments in trials) need to recognise within-season fluctuations in farmers' labour costs; an economist's help may be needed to select the most appropriate daily value or values for hand labour.

The use of herbicides may be useful to certain groups of farmers, and not to others (e.g. those unable to afford them). Weed research programmes should identify their clientele and, if necessary, consider separate trials to benefit the different groups.

SESSION VI: REGIONAL ACTIVITIES ON BEANS IN EASTERN AFRICA

A Review of Activities of the Eastern Africa Bean Programme

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CIAT, Debre Zeit, Ethiopia

Bean Research in National Programmes

Previous speakers at this workshop have reviewed the importance of conducting research to increase the productivity of bean growers in Eastern Africa. Research on beans has a long history in this region and national programmes have continued to develop during the past few years, as indicated by the number of scientists attending this meeting.

Recent meetings of national bean research co-ordinators have emphasised two particular needs among many others: training of research staff, both graduates and technical assistants; and infrastructural limitations to the effective deployment of the available research manpower, especially in the areas of seed storage, transport for on-farm research and field equipment not available for local purchase.

Access to, and the utilisation of, new germplasm has been uneven within the region. Opportunities for exchange of research methodologies, bean germplasm, literature and other results among national bean programmes have been lacking in general until recently. A questionnaire survey of all bean researchers known to CIAT in Africa in 1985 identified also a critical need for improved access to information and documentation. One bright spot was the emergence three years ago of the Phaseolus Bean Newsletter for Eastern Africa, compiled and published by Kenya's national programme at Thika.

Farmers' adoption of research results has been inadequately documented but appears to have been moderately successful in certain cases of new varieties. For example, a recent survey suggested that up to 40% of bean production in the Kabale District of S.W. Uganda comes from the varieties K20 and Kibanima, released between 1968 and 1972.

Objectives and Organisation of CIAT Bean Programme in Africa

Guided by an initial meeting of national bean researchers held in Malawi in 1980 (CIAT, 1981), CIAT's Bean Programme aims to support national efforts in three particular areas: genetic improvement, the development of more productive cropping systems and the training of staff. From a beginning in 1983 in the francophone countries of the Great Lakes Region, three separately funded regional bean programmes have been developed (Table 1). These programmes are organised and managed in a manner that is intended to combine advantages of decentralisation (daily contact with a large number of national programmes and agro-ecological zones, and smaller groups of expatriates less likely to dominate national programme decisions) with those of centralisation (easier interdisciplinary teamwork and a critical mass). The distribution of regional staff is shown in Table 1; in each case, CIAT staff are assigned by agreement to work with a host national programme while retaining regional responsibilities which, in some cases, extend beyond the borders of a single subregion. The decentralised model is felt to be particularly appropriate to Eastern Africa, where national programmes are generally more developed than in the other two regions.

Table 1. Staffing and Location of CIAT Regional Bean Programmes.

	GREAT LAKES (Swiss D.C.)	EASTERN (USAID / CIDA)	SOUTHERN (CIDA)
Agronomists	Rwanda	Ethiopia* / Uganda	Tanzania
Breeders	Rwanda*	Uganda	Tanzania/Malawi
Pathologists	Rwanda		Tanzania*
Entomologist			Tanzania
Nutritionist	Rwanda		
Socio-economists	Rwanda	Uganda	

* Regional Coordinator

Regional Programme for Eastern Africa

This programme, coordinated from Ethiopia, is supported by two donor organisations: USAID and CIDA. Its activities are planned and monitored by a steering committee that now meets once per year (more frequent meetings were useful during the formative stages). This committee is composed of the national bean research co-ordinator or team leader from each of the four countries (Ethiopia, Kenya, Somalia, Uganda), CIAT's regional co-ordinator and a representative of each donor organisation.

In order to encourage the strengthening of national programmes that are more likely to remain effective after the withdrawal of external support, the Eastern Africa regional programme does not run separate field trials. Instead, every effort is made to support national teams in conceptualising, planning and carrying out field research, for which each national team retains the responsibility and the credit for its achievements. The general functions of the steering committee are to guide CIAT in its implementation of support functions and to set priorities for the region. Specific topics that require agreement within the committee include strategies and plans for implementing the following activities:

- o Selection of research priorities with regional application;
- o Regional germplasm movements, nurseries, etc;
- o Regional training programme;
- o Organisation of workshops and monitoring tours;
- o Identification of regional needs for consultancy services from
- o CIAT, from within the region or from elsewhere;
- o Annual work plan covering all the above (submitted in draft by the regional coordinator);
- o Allocation of financial resources where discretion is provided within the budget; i.e. for collaborative research subprojects, capital equipment for national programmes, training and workshops.

A separately funded Eastern African programme offers advantages of a reasonably small steering committee for decision making and of a manageable yet critical mass of scientists for general meetings of a technical nature, such as this workshop. Training courses have also been organised separately within this, and other, regional programmes.

Many other activities, however, have been integrated across regional boundaries so as to achieve greater efficiency and effectiveness. These activities include Africa-wide workshops on special topics, training and familiarisation visits to other national programmes and the exchange of germplasm.

Provision of Germplasm

Introduction of germplasm to widen the base of national variety development programmes have been intensified, particularly in Ethiopia and Uganda.

As a short-term strategy, the African Bean Yield and Adaptation Nursery (AFBYAN) was assembled from released varieties or the most promising advanced material offered by national programmes in Eastern, Central and Southern Africa. Initial sets were distributed to Ethiopia and Uganda for evaluation at one key site in 1986. Seed multiplication now permits multi-locational testing within each country in 1987.

Assistance in overcoming locally important problems is being provided in the form of specific nurseries, including those developed against bean common mosaic virus (BCMV), against beanfly, and for drought adaptation.

Advanced breeding materials from Latin American programmes have been introduced into national systems. In the case of Uganda, local scientists made their own selections in Rwanda, which were given to Uganda after harvest; these will be developed there for the south-western part of the country. A further approach to revitalising quickly Uganda's ability to identify new varieties for farmers has been the return to Uganda of progeny from crosses at CIAT between K20, a variety released by the Uganda programme in 1968, and sources of resistance to diseases that have been its principal limitation.

Ethiopia conducted a preliminary evaluation in 1986 of some 1200 lines (in unreplicated rows) which sample the range of diversity available in the CIAT germplasm bank. Some materials already appear promising and have been advanced within the national system; further instructions may be made from those sources now identified as the most promising, while the increased seed is evaluated in other agro-ecological zones. Uganda is now following a similar approach with the same set of materials. In the smaller bean programme of Somalia, a much smaller set of materials has been introduced this year using the primary criterion of adaptation to other hot, dry regions of the world.

Regional Collaborative Research

As neighbouring countries often share similar agro-ecological zones and production constraints at the farm level, purposeful collaboration among national programmes towards solving research problems is a further potential of a regional programme. Not only are limited resources used more efficiently through concentration of effort by different national programmes upon complementary aspects of a problem shared by them, but also the analytical abilities of national programme scientists are enhanced through collaborative planning sessions and peer group review of research progress.

The role of the regional programme in these "network" activities is two-fold. Firstly, the programme can catalyse collaboration among countries so that their understanding of shared problems and their rate of progress in exploiting research opportunities are greater than would be likely through national research conducted in isolation. Secondly, a regional programme should have the technical backup to be able to feed into national programmes the new germplasm, research methods and scientific documentation that is required and requested.

Three kinds of collaborative research have been recognised by the regional steering committee, and are to be supported technically and (in part) financially through the regional programme:

- Across-countries evaluation, e.g. the African Bean Yield and Adaptation Nursery (AFBYAN). This regional variety trial not only permits each national programme to evaluate promising or released varieties from other national programmes, but also enables the identification of homologous locations or agro-ecological zones for possible future transfer of varieties and research information.

- Division of effort on a common research topic, e.g. regional strategy for beanfly research. National programmes vary in their present abilities to tackle the integrated control strategies of host-plant resistance breeding, ecological research leading to a degree of cultural and/or biological control, and use of insecticide. Some specialisation of effort and polling of results has been agreed among national programmes.

- Regional leadership roles on selected priority topics, e.g. bean breeding for disease resistances. National programmes are hard-pressed to devote adequate attention to all the important bean diseases, and ideal conditions for specific screening of germplasm are found in certain locations. Within Eastern Africa, Uganda is taking a leadership role on ascochyta blight, while Ethiopia will do the same for bean rust. Key research techniques are being developed by the leading programme, which will proceed to conduct initial screening of germplasm to identify effective sources of resistance, and assist informally with training for other programmes. However, other interested national programmes are encouraged or assisted to conduct yield loss assessments and to use resistance sources in their own breeding programmes.

Regional programme funds up to US$10,000 per year are available to successful proposers of collaborative research projects. Proposals must meet the priorities set by the steering committee, and renewal is subject to satisfactory reporting and sharing of results. Regional workshops will be one of several means of reporting results.

On-Farm Research

The past three years have been marked by a considerable improvement in understanding farmers' constraints in bean production and of the types of innovation that show promise at the farm level. While the encouragement of on-farm research has received considerable attention from the regional bean programme and from CIAT scientists of all disciplines, the methods used have varied. The staffing and organisational structure of national research institutions, as well as the relative importance and complexity of bean production within local farming systems, have influenced the nature of CIAT's involvement in different countries.

For example, where farming systems research (FSR) teams have been developed in bean-producing areas, support has been offered as needed both to the FSR team and to its linkage with local commodity research programmes. Commodity researchers based on an experiment station generally need some personal experience of on-farm research if they are to appreciate and make use of information gathered by an FSR team. In the absence of a specific programme for FSR, commodity teams need to be able to diagnose farmers' requirements and to test technology under realistic conditions.

Diagnosis of bean research needs in Ethiopia has relied heavily upon the results of general surveys of farming systems in selected areas, followed immediately by verification trials of promising new varieties. The latter type of trial provided additional opportunity to understand farmers' management practices to the priority problem of weed control. While a shortage of labour at the annual peak of farm activities prevents hoeing of pulse crops, broadcast planting at a density higher than the recommended density appears to reduce crop loss to weeds. With this knowledge, extension recommendations for row planting have been modified and the possibility is being investigated for gaining some control of weeds through selection of a variety having a more vigorous growth habit (Tilahun Mulatu, 1986).

The design of technology to resolve priority problems in bean production is demonstrating increasingly the value of collaborative research and information exchange. A case in point is the development of control of beanfly, the principal insect pest of beans in Africa. A wide-ranging programme for insecticidal control in Zambia, conducted over the last few years, identified seed treatment with endosulfan as an effective and inexpensive means of control. On the basis of these experimental results, Rwanda has moved straight to on-farm testing of this seed treatment, including an assessment of farmers' abilities and extension requirements related to the safe application of an insecticidal slurry.

Training at CIAT, Colombia

Short Courses

The only headquarters course for group training that has been used for scientists from this region is the Seed Production and Technology Course. This course has been offered occasionally in English, but, like other headquarters courses, its orientation is primarily for Latin America.

Individual Training for Visiting Scientists

Several breeders and pathologists from national programmes of the region have spent periods of two to four months at CIAT. Working directly with CIAT staff, visiting scientists can update their techniques where necessary and acquire new techniques for specialised applications. Two or three scientists from Eastern Africa can be taken in one year; plans for 1987 include two breeders and one entomologist, in response to specific requests related to a defined need in a particular national programme. In view of the expense and limited range of relevance for Africa of training at CIAT headquarters, there are no plans to expand this activity beyond its present level.

Regional and National Training Courses

Ethiopia Bean Research Technicians

A two-week course was arranged at Melkassa in August 1986 for seventeen research technicians from seven research locations. Resource persons were drawn from CIAT Eastern and Southern Africa programmes and from the Institute for Agricultural Research (IAR), Ethiopia. This course focussed on field research methods, with alternating sessions of theory and practice.

Uganda Course for Research Technicians

A similarly organised two-week course was held at Mukono, Uganda, in June 1987, for nineteen research technicians and recent graduates from the Uganda bean programme and two technicians from Somalia's grain legume programme.

Ethiopia Course for Research Agronomists

A two-week course was conducted at Nazret in February 1987 for 50 graduate agronomists, conducted and sponsored jointly by IAR, CIMMYT and CIAT. Other training courses within the region are envisaged. A course on Weed Management Principles and Methods has been approved by the Steering Committee for Uganda for early 1988.

Provision of Training Materials

Audiotutorial Units

CIAT has prepared more than 100 audiotutorial units, each comprising a slide set, a guidebook, a commentary on sound cassette and a transcript of the commentary on a particular theme. Several have been translated into English, others revised to reflect bean production conditions in Africa, and others have been developed specifically to meet needs on this continent.

The following units are available through the regional programme and are being distributed on request to the principle research and training institutions of member countries:

- The cultivated species of Phaseolus
- Morphology of the common bean plant
- Stages of development of the common bean plant
- Seed morphology and development
- Principle diseases of beans in Africa
- Main insect pests of stored beans and their control
- The biology and control of purple nutsedge
- Good quality bean seed
- Essential elements for successful seed programmes
- Principles of intercropping in beans
- Bean production systems in Africa
- Bean diseases caused by fungi and their control
- Crossing in beans (in press)
- On-farm research for bean improvement (in preparation)

These units can be used for self-teaching. However, experience with their use in training courses in the region indicates that the taped commentary is better replaced by a teacher who has first familiarised himself or herself with the content of the slides and guidebook. A copy of the guidebook should be provided to each student. Programme leaders or university staff may also find it useful to select among the set for slides that can be combined with their own for illustrating a particular topic. Suggestions for future preparation of new units would be welcomed.

Written Materials for Training

Materials developed as handouts for the local courses described above are stored on computer diskettes, to facilitate their modification to specific needs of future courses.

Equipment for Training

Slide projectors, overhead projectors and hand-held calculators are made available through the regional programme to local institutions for use in courses and in their follow-up.

Academic Training

The regional programme has received funds for a number of post-graduate scholarships. These scholarships are available to scientists of all disciplines important to the improvement of bean production, in accordance with each national programme's priorities, following approval by the Steering Committee. Scholarships are tenable at local universities or at other universities in the region or overseas. Thesis research conducted locally and on relevant issues is encouraged, and CIAT's dispersion of regional scientists in a range of disciplines to five locations in Africa increases the opportunities for local supervision.

At present, a Ugandan bean entomologist is undertaking coursework towards an M.Sc. degree at Sokoine University of Agriculture, and thesis research will probably be conducted in association with the SADCC/CIAT Southern Africa programme. An Ethiopian entomologist is conducting research towards a Ph.D degree from Simon Fraser University, Canada, on the mangement of beanfly in Ethiopia. Several other candidates are awaiting a university.

Workshops and Monitoring Tours

Africa-Wide Strategic Workshops

A workshop on beanfly was organised by CIAT in Arusha, Tanzania in November, 1986. This workshop united bean entomologists and breeders from Africa and elsewhere to assess the state of knowledge concerning the principal insect pest of this crop in Africa, and to design a strategy for collaborative research leading to its control. Participants, invited for their experience and research interest rather than to represent a particular country or institution, included entomologists from Ethiopia, Kenya and Uganda. Proceedings are being published by CIAT, and recommendations are being implemented to modify the Africa Beanfly Resistance Nursery and initiate collaborative research in several countries on bean fly biology and ecology.

A second workshop in this series will treat the topic of Breeding for Disease Resistance in Beans. This meeting for breeders and pathologists will be held in Rwanda in November, 1987 under the auspices of the Great Lakes bean programme. A third workshop, dealing with issues in agronomy, is planned for an Eastern Africa location in 1988.

Multidisciplinary Regional Workshop

The present workshop is the first example. Its success or otherwise will determine the utility of this form of meeting and any adjustments that may be necessary.

Monitoring Tour

Three members of the Uganda programme made visits to the Rwanda programme which hosts CIAT's Great Lakes regional programme. Advantage was taken of the similarity in environmental conditions between the two countries to select germplasm in the field and to discuss varietal improvement and on-farm research approaches that have been found useful in Rwanda. Other tours are planned.

Bean Information Services in the Region

CIAT Bean Information Centre

CIAT operates a Bean Information Centre at its headquarters, with core funding and IDRC project funds. In addition to publishing Abstracts on Field Beans, the centre has compiled and distributed three bibliographies on bean research in Africa (Lopez, 1983; CIAT, 1984; CIAT, 1986). The most recent volume includes "fugitive" literature obtained by means of personal visits by a consultant to bean researchers throughout the region.

Current Contents Service

A free monthly service provides researchers and libraries with current contents for a wide range of agricultural journals. The page charges for photocopies requested by bean researchers are met by coupons distributed by regional and national co-ordinators. Regional co-ordinators also assist in updating the distribution lists.

Conclusion

The regional activities outlined above are likely to be successful in meeting all three objectives only if they are undertaken with determination and in partnership. This requires that regional staff work alongside national programme staff as colleagues. The discrete categories of activity listed here do not adequately reflect the day-to-day work and even informal training that should be implicit in technical advice and collaboration. Nor has mention been made here of the identification, purchase and provision of equipment and supplies to several national programmes.

These activities should be only seen as a start. The effectiveness of the steering committee in instigating new and follow-up activities is likely to be due in large measure to the detailed advice its individual members receive from other scientists in the region. This workshop has an important role to play in identifying the needs and opportunities for strengthening bean research throughout the region.

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SUMMARY OF DISCUSSION

Theresa Sengooba, Chairman
Habtu Assefa, Rapporteur

Priorities for Regional Research and Training

What attention is being given to conservation of bean germplasm?

National programmes have their own needs for medium term storage, and the Steering Committee can consider requests to assist in the development of these facilities. In this way Ethiopia has developed a bean storage coldroom at Melkassa.

CIAT has accepted the responsibility for maintaining the world's largest bean germplasm bank. A duplicate copy of the bank now exists in Costa Rica, and present construction by Brazil is intended to maintain permanently a duplicate set. It might be useful to have a set stored somewhere in Africa, but this would require a major financial commitment. CIAT is firmly committed to a policy of open access by all to the germplasm bank.

African germplasm is introduced to the world germplasm bank after an intermediate generation is grown out in third-country quarantine, at the National Vegetable Institute, Wellesbourne, UK.

Research on utilisation of beans has not been emphasised. Where do we stand?

This workshop has reflected the lack of attention generally being given to this important field. We have great difficulty at present in predicting the success or failure of a released variety, as there are few researchers trained & equipped to assess the post-harvest criteria applied by farmers and consumers.

More involvement of women in the research process is likely to be important. The regional programme will need to train food scientists and farming systems researchers in bean utilisation. Within the region, the University of Nairobi has a department of nutrition and food science, and Makerere University is developing a department of food science and technology. CIAT has an analytical laboratory at its headquarters, and is actively involved in understanding farmers' and consumers' needs and preferences through the Great Lakes Regional Bean Programme. Consultancy visits to this region are needed.

The importance has been mentioned of weed science, crop physiology, economics and linkages with extension. How will the regional programme assist in these areas?

Although the regional programme at present does not have staff members specialised in these fields, national programmes can use the regional programme to gain access to specialists in other ways. CIAT's bean physiologist at headquarters is available to support regional activities, and is planning to visit physiologists in national programmes in the near future to discuss their needs. In other fields the use of local consultants within the region may be more appropriate, and external consultants can be brought in where no expertise is otherwise available to the regional programme.

Field research conducted with national scientists, workshops, training courses and a small number of postgraduate scholarships are the principal means available to the regional programme to encourage research in these and other less familiar areas. The regional programme can help national programmes attain a balance among the various disciplinary skills needed.

Some problems are of high priority only in one country of the region, e.g. acidic soils, or the production of farmers' publications in Uganda. Does the regional programme have a role?

The Steering Committee and CIAT will have to examine each case on its merits in relation to the efficient use of regional resources. The support of a regional research project requires that the topic be a priority for all or most members of the Steering Committee. On the other hand, training courses can often be most effective when tailored to country-specific needs.

How can we standardise research methods so that communication among researchers is facilitated and results are more readily extrapolated?

Commonly the first step is a workshop of specialists focussed on a problem area (e.g. Bean Fly Workshop in Arusha in 1986). This is normally followed up by one or more regional research projects. Collaborative research by one country should lead quickly to the identification or verification of appropriate research methods; these can be disseminated among other countries by means of monitoring tours. Familiarisation with methods used at CIAT, for example, is one component; these are demonstrated in many of the audiotutorial units produced by CIAT.

Institutional Issues and Funding

How can the activities developed through the regional programme be sustained beyond the termination of the CIAT regional project?

CIAT's policy is to develop a lasting relationship in the region, rather than a project to be phased out after a few years. A termination of project funding need not bring an end to contact between CIAT and national agricultural research systems (NARS). CIAT is committed to the development of effective and durable research capacity in Africa; project assistance to the strengthening of national programmes should make these programmes more attractive investments for national governments. Donor funds can be regarded as a catalyst for launching new activities, while the nature of the collaboration between CIAT and NARS can be expected to evolve as the capabilities and needs of NARS change.

The regional programme strategy of supporting collaborative regional research subprojects (for example, bean rust in Ethiopia, CBB research in Uganda, etc.) has the potential of developing regional centres of expertise within each NARS for selected priority areas. This strategy encourages NARS to exchange services among them, rather than being dependent on CIAT or other external sources.

What is the status of Kenya's participation in the regional programmes?

Kenya is free to participate as fully as it wishes in germplasm exchange and workshops. However, in the absence of a formal agreement to indicate that a country wishes to collaborate in the regional programme, CIAT unfortunately is not able to use existing project funds within the country for training courses, staff development through postgraduate scholarships, research support, and so on. Kenyan scientists are invited to participate in regional activities, and Kenya has continued to take part in all meetings of the Steering Committee.

How are the funds received from different sources integrated within the regional programme?

The Steering Committee sets priorities for the regional programme, and approves specific activities that utilise the resources that are available to it. Each country is represented on the Committee, as well as CIAT and the two principal donors to the programme.

Future Workshops

It was agreed that this workshop would be followed by similar multidisciplinary workshops on bean research in Eastern Africa after every two years.

Workshops focussed on specialised topics would be held annually or thereabouts, and often in collaboration with the bean programmes of other regions of Africa. A workshop on beanfly having been held already, priorities suggested for the future were varietal improvement, bean diseases, agronomy and weeds.

The Steering Committee's proposal to develop monitoring tours around regional research projects was endorsed.

A P P E N D I X

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