THIRD SADC/CIAT BEAN RESEARCH WORKSHOP

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PREFACE

This volume reports the proceedings of a workshop on bean research in southern Africa organised by the Southern African Development Community/Centro Internacional de Agricultura Tropical (SADC/CIAT) Regional Programme on Beans in Southern Africa, with financial support from the Canadian International Development Agency (CIDA).

The SADC/CIAT regional bean programme is the bean component of the Grain Legume Improvement Programme of the Southern African Centre for Cooperation in Agricultural Research and Training (SACCAR) and is part of a network of interdependent regional projects managed by CIAT in Africa. This workshop is the third in a series of multidisciplinary regional workshops considering research on the common bean in SADC countries. Such workshops are designed as fora for the assessment of status, methods, quality, future direction and needs of research, through peer review by scientists within the bean network. This document is the twenty-seventh in a series of proceedings of various types all of which serve research on beans in Africa. This publication was made possible through support provided by CIDA. The activities of the bean research networks in Africa are further supported not only by CIDA but also by the U.S. Agency for International Development and the Swiss Development Cooperation. The opinions expressed in this document are those of the authors and do not necessarily reflect the views of these donor agencies nor of CIAT.

Further information on regional research activities on the common bean in Africa is available from:

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CIAT Regional Bean Programme, P.O. Box 6247, Kampala, Uganda.

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No. 15. First Pan-African Working Grop Meeting on Anthracnose of Beans, Ambo, Ethiopia, February 17-23, 1991.

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An additional character for sexing the adults of the dried bean beetle *Acanthoscelides obtectus* (Say)(Coleoptera: Bruchidae). J. Stored Prod. Res. 30 (1): 61-63.

No. 8. Wortmann, C.S., M. Isabirye and S. Musa. 1994. *Crotalaria ochroleuca* as a green manure crop in Uganda. African Crop Science J. 2(1):55-61.

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No. 10. K. E. Giller, F. Amijee, S. J. Brodrick, S. P. McGrath, C. Mushi, O. T. Edje and J. B. Smithson. 1992. Toxic concentrations of iron and manganese in leaves of *Phaseolus vulgaris* L. growing on freely-drained soils of pH 6.5 in Northern Tanzania. Communications in Soil Science and Plant Analysis, 23 (15&16), 1663-1669.

C O N T E N T S

SESSION 4 : CROP PROTECTION

SESSION 5 : PLANT IMPROVEMENT

[1] abstract only; [2] offered paper; all other papers invited

SESSION 1: OPENING SESSION

OBJECTIVES OF THE WORKSHOP

D.J. Allen

Under Secretary, Chief Research Officer, ladies and gentlemen, the theme of this workshop is "beans, genes and research for increased productivity and sustained self-sufficiency : the SADC/CIAT regional workshop as a model". This is the third of our regional workshops which we have held during the first 5 year phase of the SADC/CIAT regional bean programme, which has been funded by CIDA. The first regional workshop was also held here in Mbabane, on the same dates 3 years ago. In 1990, we held the second, in conjunction with SUA/CRSP in Morogoro, and the proceedings have now been published and distributed.

The objectives of the workshop are to appraise recent scientific progress made by recipients of academic scholarships and leaders of regional collaborative research sub-projects in southern Africa, and so to foster multidisciplinary peer review of research conducted within the bean network.

The proceedings of the workshop will follow the format adopted for the previous regional workshops, with presentations being given in six successive sessions. Invited papers, of 25 minutes duration, will describe research conducted in sub-projects as well as the results of thesis research. Offered papers, given by scientists selected on a competitive basis, outline studies on beans not directly supported by SADC/CIAT, and are of 15 minutes duration. You will see from the Programme that there are to be 6 sessions arranged by discipline and allowing for ample discussion, to be recorded by rapporteurs. It is our intention to publish the proceedings as usual, but we will also distribute to you all a spiral bound record of the abstracts during the course of this workshop.

This third workshop marks the end of Phase 1 of SADC/CIAT : the next phase will be smaller and more Pan African, to make more efficient use of shrunken resources. So it is timely to take stock of what has been achieved and to identify gaps in what priority constraints are not yet adequately addressed by our regional bean network. The objective of the discussion groups to be held in the final session is to give guidance to the Steering Committee (which convenes for its 13th meeting immediately after this workshop) to the allocation of resources proportional to the perceived importance of that particular research topic as part of the regional agenda.

On behalf of CIAT, I should like to welcome you all to this workshop which we hope you will find valuable, and to thank you for coming to join us. Special thanks to the Under Secretary for doing us the honour of opening the workshop for us.

Thank you !

SACCAR'S ADDRESS AT THE OPENING CEREMONY

P.D. Mkhatswa, on behalf of M.L. Kyomo

Distinguised guests, ladies and gentlemen, the Bean Research Project is one of the projects under SADC's Grain Legume Improvement Programme (GLIP), that also embraces the Groundnut Research Project and the Cowpea Research Project, executed respectively by ICRISAT and IITA. The Bean Research Project is executed by the International Centre of Tropical Agriculture (CIAT). These projects were initiated by SADC Heads of State after the drought that we had in the early 1980's. These projects are for the benefit of SADC, not for the benefit of the executing agencies. Nationals of the SADC countries therefore must work to make these projects a success. If they fail, it is our failure.

Ladies and gentlemen, you have heard from Dr. Allen that Phase I of the Bean Research Project is coming to an end, and another phase is about to start. This phase seems likely to include more countries and presumably less funds. This calls for more effort from the nationals of SADC. In Swaziland, the Bean Research Project has had impact. Our predominant bean variety is not liked by farmers. We have now released three new varieties to the farmers, and our next task is to produce seed.

One aspect of the Bean Project that I like is its Steering Committee through which nationals are able to voice what they need for their countries, and nationals should be clear on those needs. With the support of SACCAR and national governments, I hope we in SADC will be able to use this project effectively for our full benefit.

Thank you !

OPENING ADDRESS

A.F. Hlatshwako

Mr. Chairman, project leader, distinguished guests, ladies and gentlemen, it is a pleasant experience for me to be given this opportunity to make an opening address on the occasion of this third SADC/CIAT regional bean workshop, and for this I wish to thank the workshop organizers for affording me this unique privilege.

It is fitting to begin my brief address by welcoming each and everyone of you to the Kingdom of Swaziland. Swaziland, as you may all know, is the smallest country within the SADC region, occupying an area of about 17,360 square km. Its current population is estimated to be 800,000. Swaziland is geographically divided into four agro-ecological zones which allow for a wide diversity of cropping patterns and farming systems. The highveld, which streches from the north to the south on the western side of the country, has a cool climate with an average annual rainfall of 1200 mm. The average altitude in this region is 1700 m above sea level. Farming activities in this region are limited by steep slopes. Beans are mainly grown in this zone where natural and exotic forests are found. The middleveld, which lies east of the highveld, is the most suitable zone for agricultural activities. Most of the major crops are grown in this zone. The lowveld lies east of the middleveld and is characterized by a semi-arid climate and high temperatures.

The national agricultural policy is to achieve self-sufficiency in food production, improve the nutritional status of rural communities and of low-income groups in urban areas. Beans as a legume crop can provide cheap vegetable protein to these groups. However, beans are grown on a small acreage in the country. Farmers normally grow their own varieties which are determinate and of cranberry type. It is my belief that these farmers could benefit from improved bean technologies. Previous research work has shown that improved varieties are higher yielding than the local varieties. Thus, if farmers could adopt the new improved high yielding varieties, this country could achieve its goals of attaining self-sufficiency in food production and improving the nutritional status for the low income groups in urban and rural communities.

We are aware that the international agricultural research centres and the national agricultural research system have developed improved varieties and yet national bean production is not improving. I am reliably informed that Swaziland has, over the last five seasons, concentrated on the promotion of CIAT lines, Carioca, BAT 1713, PVA 894, and PVBZ 1782. Research officers inform me that farmers who have participated in on-farm trials have time and again come back for more seed of these bean lines because their harvests have all been consumed.

Ladies and gentlemen, I have indicated that here in Swaziland high yielding bean lines, Carioca, BAT 1713 and PVA 894 have been identified, but farmers do not grow them yet on a large scale. This might be due to a number of reasons which may not be known to us. It is therefore the duty of this workshop to share experiences and challenges in an effort to develop appropriate research methodologies. Funding for national agricultural research programmes is inadequate. Budget cuts are experienced annually. Financial support, be it from national, regional or international sources, is diminishing. I hope the workshop will focus on balancing technology development and technology transfer in terms of monetary value, human resources and time. Many technologies within the region have been developed in the past but these have never reached farmers and therefore have had practically no impact on farmers' lives and/or aspirations. That was a waste of money, time and human resources. Ladies and gentlemen, these past experiences should not be repeated. Finance must be viewed as the major constraint to our efforts. National scientists should work hard on well planned programmes in order to develop our countries. Human population is increasing at an alarming rate, and this is a challenge to all of us here to provide enough food for them and also to improve their standard of living. Farmers should be encouraged to grow these beans.

Ladies and gentlemen, without any waste of time, I declare this meeting officially opened.

Thank you !

SESSION 2 : ON-FARM RESEARCH

EXPERIENCE WITH ON-FARM RESEARCH ON BEANS IN TANZANIA

O.T. Edje

ABSTRACT

Our on-farm activites in Tanzania cover four regions: Arusha, Kilimanjaro and Tanga in the north, and Kagera in the north-west of the country. The first three regions are maize-based cropping systems and Kagera is banana-based. Our research activities in these regions have included : variety trials, farmer managed trials, seed distribution, a pilot seed scheme, soil fertility and agroforestry. These activities have been carried out in collaboration with farmers, national programme scientists, extensionists and NGOs, notably : the Tanzania/Netherlands Lake Zone Farming Systems Project, SECAP and Global 2000. In these districts where we have been active, a logical sequence of on-farm trials have been set in place, ranging from exploratory work to demonstration.Our strategy is a farmer participatory approach that integrates farmers in the generation of technology, and this has led to the higher adoption rate of technology, especially of varieties.Exploratory trials in Lushoto District, Tanga Region, using the modified minus one design, identified lack of improved variety and soil infertility as the main constraints limiting bean production in the district. Both constraints have been successfully addressed. The involvement of farmers in varietal selection for on-farm research is now institutionalized. Evaluation techniques include the use of the ordinal, coin and questionnaire methods for the assessment of production, marketing and consumption characteristics. The nutritional disorder once referred to as "Usambara mottle" was diagnosed as potassium deficiency, to which a potential solution has been found.Agroforestry trials set up in 1988 in Lushoto, with the objective of erosion control, soil fertility improvement and provision of stakes for climbing beans are now yielding encouraging results. However, we still face the following challenges : the institutionalization of OFR, the exploitation of opportunities for relay intercropping with climbers in the southern highlands, and soil fertility improvement of the <u>tumbas</u> through use of fast growing and easy to eradicate legumes such as <u>Crotalaria</u>.

BEAN-BASED INTERCROPPING SURVEY

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ABSTRACT

As part of the cropping systems sub-project of the SADC/CIAT bean improvement effort, a formal survey was conducted on bean-based intercropping systems. The main objective of the survey was to investigate how farmers grew beans particularly in association with other crops. This knowledge would form the basis for future intercropping studies involving beans. It was realised that farmers' production systems differed and were complex, hence are not considered in current research effort. The survey uncovered a lot of salient points in the farmers' production systems among which are cultural practices, varieties, intercropping systems -their causes, constraints and potential. The survey highlights a number of questions and makes recommendations for consideration in future research efforts in bean research in general, and bean-based inter-cropping in particular. Paramount are issues of labour shortage, poor soil fertility and seed shortages in the system.

INTRODUCTION

The survey was conducted as part of the SADC/CIAT bean improvement effort which partly financed the study. The objective of the study was to gain an understanding of how farmers grow beans, particularly in association with other crops. This understanding was needed in order to develop bean production technologies that were more appropriate for the farmers' bean production systems. It was noted that whereas most bean research involved growing beans in monoculture, farmers were seen to grow beans in association with other crops. The objectives of the survey were to determine with which crops beans were most commonly associated, and what was the nature of the principal differences between the two systems, of monoculture and intercropping. Although a general questionnaire was developed in Zambia by the author and other scientists, other SADC countries also implemented the survey, but this report concerns only the survey conducted in parts of Zambia, notably Serenje district, which was considered representative of the intercropping systems. This paper summarizes findings from Serenje district.

MATERIALS AND METHODS

The questionnaire, developed by scientists on the Adaptive Research Planning Team (ARPT), was pre-tested in Solwezi and Kasama districts of north-western and northern provinces of Zambia, respecively. Before it was sent out to participating countries, the questionnaire was also discussed and modified to suit further cropping systems by collaborators in Arusha, Tanzania of the SADC/CIAT Regional Bean Programme. Thereafter, individual countries administered it and processed the information. In Zambia, the survey was conducted in Serenje district by a team of agronomists and extension staff. Farmers were selected randomly from each of the extension sub-districts (blocks) in Serenje. No enumerators were used because it was intended that scientists themselves follow-up issues beyond the questionnaire when necessary. The survey was conducted in February 1991, when a crop was in the field. Scientists visited the fields and verified some of the information. Results from the questionnaire were then coded and information processed manually. It should be noted also that staff of ARPT northern and north-western provinces decided to administer the questionnaire in suitable districts in their respective provinces, but results await analysis.

RESULTS

Household labour

Although most families included several children, effective household labour available for most farm operations was often low. Thus, 40% of households reported only 2 persons (husband and wife) as full time workers on the farm. 25% of the households had a labour force of 5 people, while another 20% had 4 people, in both cases including teenage children. Farmers complained of shortage of manpower for desired levels of operation. This shortage was reflected in the frequency of labour hire, where 50 % of the households did hire labour while the other half did not. Labour was hired mostly (75%) for ploughing, primarily maize (-bean) fields (66%). The form of payment was by cash (72%), food (18%) and beer (9%). Beer parties involved large numbers of people.

Size of holding

The concept of fields to mean separate parcels of land was often misunderstood for plots planted to different crops, even if only one piece of land was involved. Nevertheless, it was reported that 40% of the households had 3 or 4 fields, with 30% owning 6 or more. Field sizes were difficult to establish, and some fields were still uncleared bush. Farmers indicated no land constraints.

Soil fertility and age of fields

70% of farmers categorized the soils in their fields as poor and needing fertilizer, while 25% had land of medium fert- ility. Only 5% had high fertility (probably in new fields). This poor soil fertility may be inherent and only aggravated by crop cultivation. All the same, even though most farmers (45%) had been in the area for 15 years or more, their fields had often been in cultivation for much shorter periods.

Main crops

Asked what they grew in their fields, all farmers had maize, in addition to which 80% had millet and 50% had sorghum as their main crops. The area for maize ranged from 0.25 to 3.5 ha with an undefined portion intercropped with beans. Again reliable area estimates were hard to obtain.

Starchy staple crops

Asked what their number one starch staple was, 75% of farmers answered maize, 20% millet, while only 5% said cassava. In second place was millet (45%), cassava (30%) and for some farmers maize (10%). It was concluded that the primary staples were maize, millet and cassava, in that order.

Relish

The main relish staple was beans (90%) followed by vegetables (exotic, then local types).

Cash source

Since many farmers paid cash for labour and exotic vegetables, it was important to determine their cash source. Asked about their main cash sources, 85% of households said from maize, while 50% included bean sales as well. Other cash sources were reported as loans (40%), piece work (40%) livestock (chicken) sales (45%), and beer sales (50%). Percentages refer only to the frequency with which a source was mentioned and not to the magnitude of cash involved, for which farmers could not give reliable figures.

Cultural practices in bean production : varieties

Nearly all farmers had more than one variety. Most farmers grew several varieties : 55% had at least 4 (-6) varieties, 30% had 2 or 3. Over 70% of the varieties were said to be climbing types, with large yellow, cream to light pink seed.
75% of farmers grew two successive rainfed bean crops per season. The first was intercropped in maize, while the second was grown sole, or intercropped with new cassava. Although the same varieties were planted both times, most (85%) farmers said the second bean crop gave better yields than the first.
However, due to multiple plantings and harvests, the actual yield was difficult to establish. Farmers' decisions for locating the current season's bean-maize crop were found to relate to the need for crop rotation (46% of respondents), to use of residual soil fertility (31%) and to land shortage (23%), though the latter was related also to soil fertility (due to shortage of fertile land).

Planting time and method

Although (first crop) planting started in October (19%), most of the planting was done in late November (52%), and early December (28%). However, farmers changed from season to season depending on circumstances like when the rains started.

Although farmers who plant late stopped planting in December, those who plant early stopped planting in November. The second crop was planted mostly in February, with a little bit sown in early March or late January. Asked about relative planting dates of crops, 94% of farmers said they planted maize and beans at the same time. Only 6% planted beans later than maize. As for the placement of the bean seed, farmers placed it in the same station with maize (47%) or placed it in between maize stations (47%), the former practice to save labour. A small minority (6%) planted beans on the side of maize ridges.

Row spacing and seed rate

Row spacing and seed rate were difficult to establish as farmers generally do not take accurate measurements. However, through demonstrations and visits to the fields, it was established that between-row spacings ranged from 80-100cm and intra-row spacing ranged from 15-100cm for maize. Beans were placed as described above, on maize ridges. Where maize was closely planted, beans were only included at some stations (no specific pattern given). Maize seed was mostly planted singly but 2 or 3 seeds per station was common. Beans were planted in 2's, though 3-4 seeds was frequently mentioned and resulting plants observed.

Fertilizer use

95% of farmers acknowledged using fertilizer in their maize-bean fields. When asked which crop was targeted, all said fertilizer was applied to, and intended for, maize. But they realised beans benefited from the "maize fertilizer". The fertilizer rates applied could not be established because farmers could not recall how much area had received how much fertilizer. Fertilizer quantities sometimes seemed inadequate for the area treated.

Bean yields

In spite of the early planting and fertilizer use (for the maize), bean yields in intercrop were very low, estimated at 500kg/ha by 95% of respondents. Realising that the second (sole) bean crop yielded higher than the intercrop, 74% of farmers thought the first crop would yield better if planted sole. But this they would not be able to do because of labour shortages early in the season at planting time of maize which receives priority. As regards maize yield in intercrop, 47% of respondents reported that beans suppressed maize yield, while 42% had not seen any such detrimental effects. A further 10% thought the maize benefited from bean association.

Disease and insect pest incidence in intercropping

About the same proportion (32%) of farmers felt that a sole bean crop would suffer more pest and disease pressure as felt that the pressure would be the same. Some 15% thought a sole crop would suffer less, while a further 21% had no idea what would happen. Farmers could not specify to what pests and diseases they referred. Farmers were further asked if they knew of any other benefits due to intercropping beans and maize. 84% said 'yes' they did, the rest (16%) answered 'no'. However, most of the benefits (seed multiplication, early relish) pointed to labour saving and soil fertility (use fertilizer on maize, compatible, increases bean yield). Some farmers mentioned risk aversion, meaning they feared planting beans after maize would lead to bean crop failure.

Bean production problems

Asked about problems with their bean production systems, 47% replied that they had some, but 53% perceived none. Farmers forsaw many potential problems, including reduced maize yields due to nutrient competition, moisture stress, as well as difficulty in weeding an intercrop. Farmers felt the maize needed fertilizer, and that the combination failed in dry years.

Bean-cassava intercropping

The majority (75%) of farmers grew a second bean crop frequently in association with cassava. Cassava cuttings are planted on the side of large ridges, 60 cm apart. Beans are then planted (1-2 seeds per station) at random on the ridge from the end of January to early February, after maize weeding. The beans are harvested after about 3 months, leaving the cassava to continue growth for about 2 years. Although bean yield was estimated to be relatively low (< 500 kg/ha), the bean crop did not seem to be affected by the cassava which had only a small leaf canopy for most of the time that beans were in the field.

DISCUSSION

Beans were found to be a very important component of the system, contributing both to household food as a relish and to family income through sales. Nevertheless, bean seed yields remain very low because of various production constraints that warrant research attention. In addition to the points mentioned above, the survey revealed a number of issues that need to be addressed; these are as follows :

Farmers grow many varieties of beans, both as mixtures and as pure types. Mixtures presumably ensure against risk as well as incorporate desirable seed characters that other components lack. The importance of varietal mixtures on-farm raises the issue of whether farmers are expecting that newly released varieties are also mixtures; and what their reaction might be to pure lines. Should researchers be developing 'composite' varieties, or components that the farmer might incorporate into his, or her, mixture ? Since farmers produce two successive crops per season, are 'new' varieties sufficiently unresponsive to time of planting ?

On varieties, research should also study and characterise farmers' preferred varieties.

As farmers bean yield could not be determined accurately during the survey, both actual and optimal yield in inter-cropping need to be assessed. Research should characterise farmers' seed rates, spacing, planting patterns, and dates.

Labour shortage was seen as much the most important factor governing farmers' decision-making, including the adoption of intercropping which may have contributed to the low yields of beans. This implies that bean production technologies (including monocropping) that are labour intensive are liable not to be adopted readily; research may be necessary to identify varieties and other practices that do not rely upon labour at peak periods. Both weeding and planting patterns were found to be affected by labour constraints, and research is needed to examine farmers' practices so that future recommendations take into account the shortage of labour in the system. Labour saving technology in bean production should be studied.

Disease and insect pest dynamics in an intercrop also need to be characterized. There was no conclusive response from farmers on the subject.

With the current high price of fertilizer after removal of subsidy, it seems possible that maize may be replaced by less fertilizer-dependent crops such as millet and sorghum as the main cereal staple in the system. The challenge for research is to intensify work on the intercropping of beans with millet, sorghum or cassava.

Bean response to direct, residual and "maize" fertilizer regimes need to be studied and compared, including the effect of new fields on bean yield.

ACKNOWLEDGEMENTS

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EVOLUTION OF RESEARCH IN BEANS IN KAGERA REGION, TANZANIA, 1988-1992

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ABSTRACT

An overview is given of the work done on beans in Kagera Region since 1988 in collaboration between the ARI Maruku Bean Section and the Farming Systems Research Section.

In on-station trials, improved varieties had outyielded the local check 'Kisapuli'. This justified testing the high-yielders in farmers' fields in mixed cropping with bananas. On-farm trials were planted in September/October (short-rains 1989 & 1990) and February/March (long rains 1990 /91). During the short rains, Lyamungu 90 outyielded 'Kisapuli' significantly though by only 5-6%. In the long rains, yields were low as a result of low light intensity, impeded drainage during early stages and drought towards ripening.

To obtain better knowledge of the local varieties ("what are we trying to improve on ?"), 14 local varieties were compared with two improved ones in pure stand in an on-station trial. Again 'Lyamungu 90 yielded 50% more than 'Kisapuli'. Several local varieties yielded in the same range as the improved ones (ca 1300 kg/ha).

It is concluded that in future trials one should carefully :

- *select several local check varieties*
- *consider the land-use system predominant in the area where the trial is conducted.*
- *Define a more specific objective of the trial (e.g. select higher yielding small white-seeded varieties).*

INTRODUCTION

In the farming system of Bukoba and Muleba Districts, three major landuse types are recognized (Friedrich, 1968) :

- The most important land-use type is the 'kibanja' in which the house is situated. The main crop in the kibanja is bananas. At the start of the short rains (September-October), the bananas are interplanted with beans.

- The second land-use type is 'kikamba'. The kikamba is devoted to annual and short-lived perennial crops : sweet potatoes, cassava, maize and sometimes beans. Kikamba can be 'upgraded' to kibanja.

- The third land-use type is 'rweya' : grassland unsuitable to be turned into kibanja or kikamba. Once in eight years (at most) an annual crop is grown (bambara groundnut, groundnut, dioscorea yam, sweet potato, finger millet) sometimes in combination with cassava.

In Bukoba, rainfall decreases westward from the coastal strip. Average annual rainfall varies from 2100 mm in Bukoba town to about 800 mm in the West. In Muleba, the rainfall gradient from North to South is more marked than from coast to West. Not far South of the District capital, rainfall is such that banana cultivation is impossible.

At the start of the Lake Zone Farming Systems Research Project, in 1988, it was realised that the best way to obtain knowledge of the farming system was to start trials in farmers' fields as early as possible to get the feel for the farmer and the cropping system. At that stage, an annual trial crop was considered most suitable as results are obtained quickly and treatments can be adjusted twice a year.

OBJECTIVES OF THE ON-FARM TRIALS

Bean variety trials done on-station (Maruku) have given strong indications that local varieties can be outyielded enormously by improved varieties. The results of an on-station trial in 1988 are shown in Table 1. 'Carioca Selection 2' yielded 2.6 times more than the local check 'Kisapuli'. This further justified testing the performance of these superior yielding varieties as compared to a local variety under farmers' conditions. This was the main objective of the on-farm variety trials.

A second objective of the on-farm trials was to get in closer touch with farmers and to gather information systematically from farms and farmers. An important aspect was the collection of sets of yield data linked to soil characteristics. Banana densities and crop mixtures were among the other data collected in the process.

A third, and final, objective of the trial in the long rains was to obtain an answer to the question :

> "Why do farmers not grow beans during the long rains while this season seems less risky because of more reliable rain ? "

RESULTS

In four seasons, a total of 130 trials were planted on-farm. The design used was a randomized complete block with two replications at each site. Sites were clustered, clusters being villages each with five sites. Each season, new sites were selected, and villages were changed after one, two or even three seasons. As can be seen from Table 1, several varieties were discontinued. Reasons were the unfavourable opinion of farmers, disappointing yield and/or poor seed quality. Lyamungu 90 was the best improved variety, both in yield and in farmers' opinion. The yield difference with Kisapuli is small (5-6%) but its consistent performance and its demand from farmers justified release of the variety.

The poor performance of Kisapuli on-station should be attributed to its exposure to full sun or perhaps to differences in soil chemical characteristics between the research station and farmers' field.

The long rains trials gave us the answer to the question why farmers are not growing beans during this season. The 1990 season was a dry one, especially towards the end of the growing period (May & June). Yields were reduced by drought stress. The 1991 season was extremely wet. In Bukoba Town, rainfall amounted to 380 and 523 mm in April and May, respectively. The result was poor light intensity for beans under the banana canopy, impeded drainage in some sites, and low temperatures.

Although disease incidence was higher than in the three earlier trials, disease was not considered to be the cause of yield loss. Growing beans during the long rains is more risky than growing them during the short rains. That our trial seasons were not exceptional can be seen from the graphs in Figure 1, that represent rainfall probabilities by decade for both the wet (Bukoba Town) and dry (Kyakakera) part of Bukoba District.

Analysis of formal interviews with 100 farmers in 10 villages (trial farmers & villages + others) has led to a better understanding of bean growing practices and problems connected to bean growing (Bosch et al., 1990). Systematic information on other aspects of the farming system has been collected (e.g. Bosch, 1990;

Bosch et al., 1990). Soil analysis data were obtained of all trial sites and proved that the kibanja soils are not all poor in available phosphorus, contrary to what is generally assumed (Milne, 1938). Banana densities, measured in all sites, appeared to be a lot higher (median ca 1500 stools/ha) than the recommended density (816-1100 stools/ha).

FOLLOW-UP ON ON-FARM PROGRAMME

Our on-farm variety trials justified release of the variety Lyamungu 90. In September 1992, seed of this variety was distributed in the Region to ca 300 farmers and Farmers' Extension Centres. The aim of this exercise is to see if adoption and spread of the variety will take place. As seed firms are not very active or effective, alternative ways of dispersing new varieties are needed. Our on-farm trials had shown that varieties that are high-yielding on-station do not necessarily yield well on-farm. The final result of our on-farm trials was disappointing : of six improved varieties tested, only one could be recommended for release.

To obtain better knowledge of local varieties, we compared 14 widely grown varieties with the two best improved varieties during the short rains 1991 in an on-station trial. The objective of the trial was to find out; "what are we trying to improve on ? " Yield results of this trial can be found in Table 2 and the Anova in Table 3. This trial again showed poor performance of Kisapuli on-station which is further proof for variety x cropping system interaction. The variety Karuku showed a far better weed suppression than the other entries. This explains why it is widely grown in kikamba, a fact that was missed in the analysis of questionnaires. Such a variety x cropping system interaction comtrasts with findings in neighbouring Uganda where an interaction was not found (Wortmann and Sengooba, 1993). Careful design of trials, and analysis of results of variety trials using clustering techniques (Mushi, 1989), should be done in future to allow for detection and interpretation of significant interactions.

Farmers' assessment of the varieties increased our insight in varietal characteristics and preferences. As a result, in 1992 the trial was repeated with large emphasis on local white-seeded varieties, as this group is popular but low yielding, meaning there is ample scope for improvement.

We hope this approach will lead to a series of trials both on-station and on-farm with a more narrow scope than the earlier trials.

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Table 1. Yields of varieties in different trials

	On-station			On-farm			
	1988	1990	1991	1989	1990*	1990	1991*
Kisapuli	387	752	848	626	387	1030	302
Carioca	1019	-	-	527	317	-	-
EMP 86	646	-	-	696	336	-	-
Lyamungu 90	539	1259	1283	664	387	1077	260
Lyamungu 85	584	1057	1075	726	385	1025	260
Lushara	-	-	1281	-	323	969	292
G 8864	-	-	-	-	-	-	256

* Long rains, all other trials were executed during the short rains
- variety not included in the trial

Table 2. Yield (kg/ha) by variety

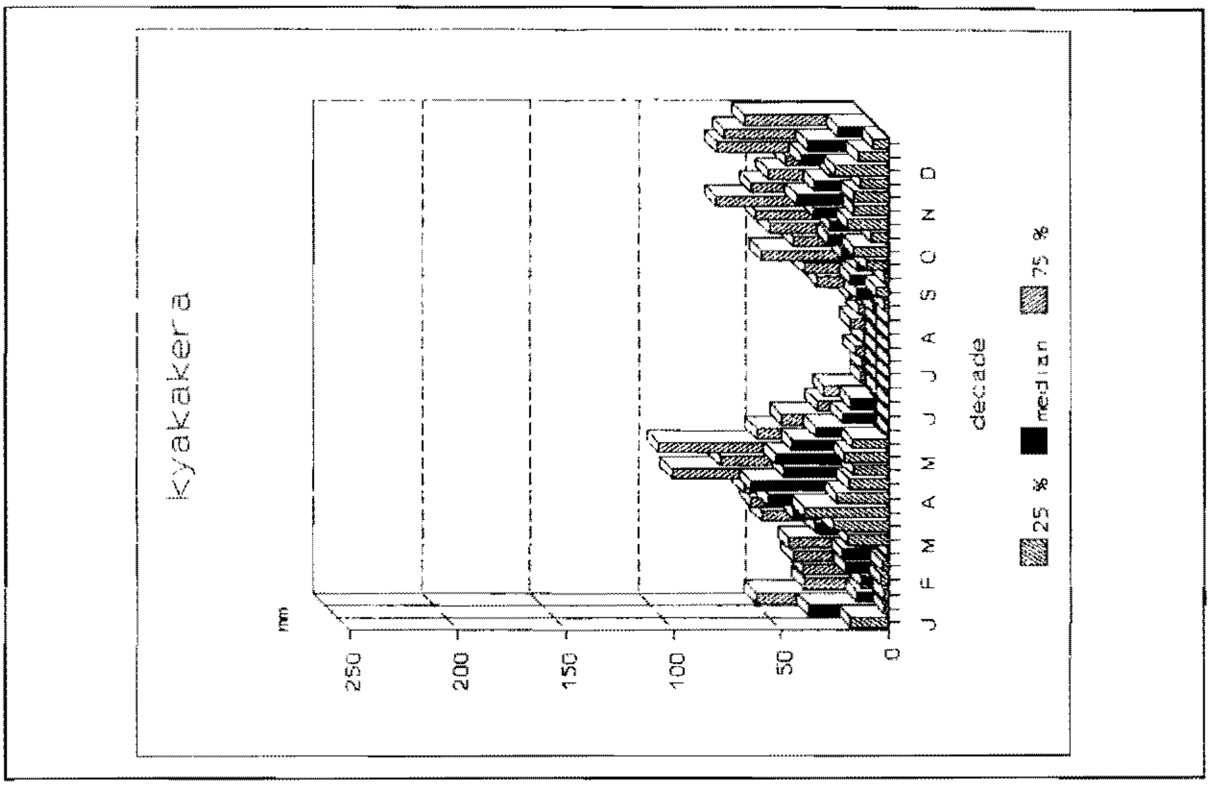
Variety	Mean	
Tibihabwa	1341	a
Lyamungu 90	1283	a
Lushara	1281	a
Mwana-mwana	1098	ab
Lyamungu 85	1075	ab
Amini	925	abc
Karuku	876	abc
Kyaburundi	873	abc
Kisapuli	848	abc
Tikyakuloza	833	abc
Raja	802	abc
Kamoshi	699	bc
Batenda-olwakyo	654	bc
Temekibira	515	bc
Kashenshe	484	c
Kaiba	481	c
Mean yield	879	

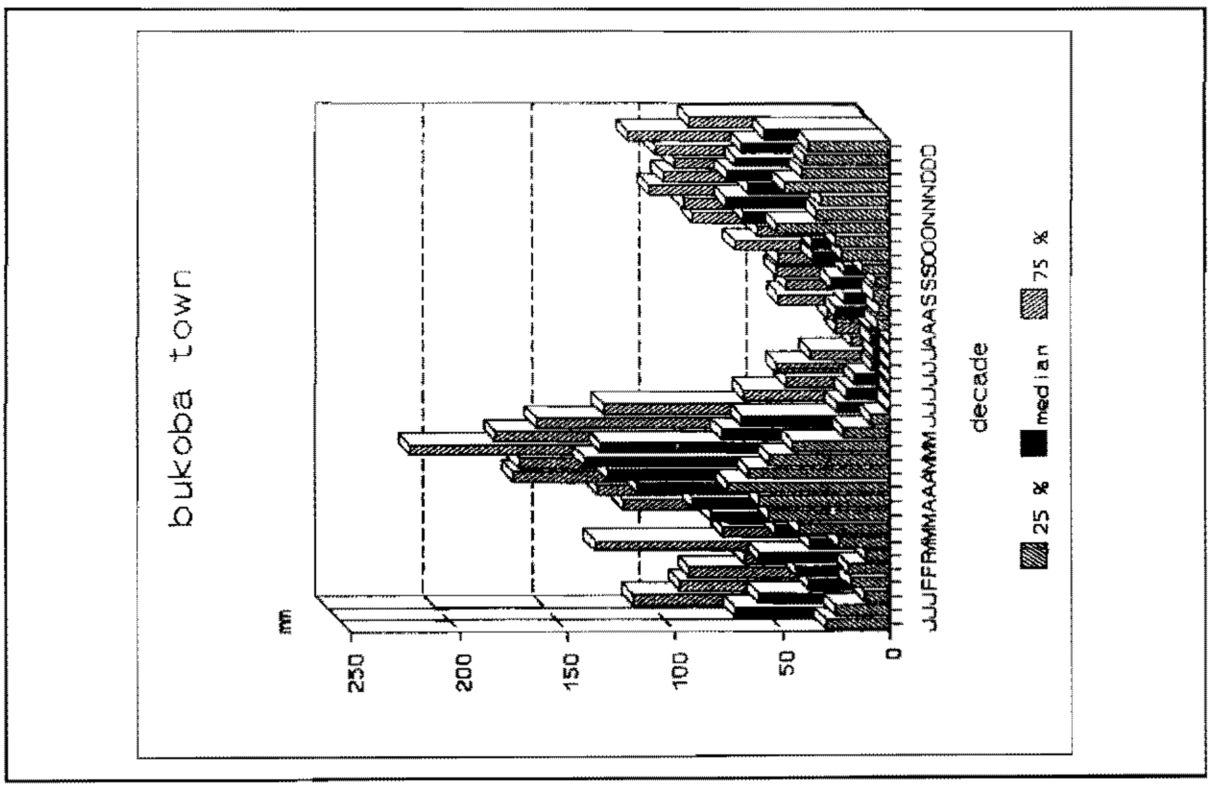
Note : Means followed by the same letter are not significantly different at P = 0.05

Table 3. Anova yield by replicate and variety

Source of variation	DF	Mean square	F
Main effects			
Replicate	2	31935.896	.872 NS
Variety	15	233159.843	6.368 **
Residual	30	36614.918	
Total	47	99142.914	

Figure 1. Expected rainfall in Bukoba Town and in Kyakakera





Based on rainfall data of 1971-1990

COMMON BEAN (*Phaselous vulgaris*) VARIETAL EVALUATION UNDER ON-FARM CONDITIONS IN SWAZILAND

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ABSTRACT

Common bean (Phaseolus vulgaris) is the most important and popular food grain legume crop grown by small scale farmers on Swazi Nation Land (SNL) and by large scale farmers. The on-farm research was conducted only on small scale farmers' fields. Seven Rural Development Areas (RDAs) were selected. The number was decreased to two in 1990/91 and 1991/92. Twenty four farmers were involved during experimentation. Four bean cultivars (Carioca, PVBZ 1782, PVA 894 and BAT 1713) were tested across the four seasons while Bonus(check) was included during 1989/90 and 1990/91 seasons. Plot size was 2 rows x 10 m with two replications per farmer. Farmers' management practices were recorded. They used both tractor and oxen for seed-bed preparation. Chemical basal fertilizer was applied at low rates while nitrogen top-dressing was not applied. Trials either received one hoe weeding or one inter-row cultivation, or neither. Data analysis was done using MSTATC software. Combined data analysis across sites (over years) was performed. Carioca gave an average grain yield of 382 kg/ha across sites and seasons. PVBZ 1782 was second to Carioca.But farmers did not like the colour or taste of PVBZ 1782. Farmer's assessments done on these cultivars revealed that farmers preferred Carioca, PVA 894 and BAT 1713 because of taste and high grain yield. However, they did not like the growth habit of Carioca, BAT 1713 or Bonus. Farmers preferred Bonus for its taste but disliked its growth habit and low grain yield.

INTRODUCTION

Food grain legumes, as a group,are second to maize in their importance in Swaziland. The major legume crops grown on Swazi Nation Land(SNL) are: beans (*Phaseolus vulgaris*), groundnut (*Arachis hypogaea*), bambarra groundnut (*Vigna (= Voandzeia) subterranea*), and cowpea (*Vigna unguiculata*), while mung beans (*Vigna radiata*) and soyabeans (*Glycine max*) are of lesser importance (Lin, 1985; Mamba,1991; Pali-Shikhulu, 1992).
Beans are one of the most important grain legumes grown. It is

a good economical source of vegetable protein which can alleviate protein malnutrition in developing countries of which Swaziland is one (Mamba et al,1988). However, the area under bean production fluctuates from year to year: estimated on SNL at 2,167, 1,138 and 4,209 hectares for 1975/76, 1979/80 and 1989/90, respectively. Average yields ranged from 468, 190 to 500 kg/ha for the three years, respectively (CSO, 1976; CSO, 1980; CSO, 1990).

The low productivity obtained by farmers on SNL is due to a number of constraints. Informal and formal surveys have indicated that poor crop management, such as low plant stand, minimal use of fertilizers and poor weed control, is among the major limiting factors. An increase in bean production would improve the human diet and also provide a source of income to farmers.

Thus, on-farm bean varietal evaluation was conducted, with the following objectives :

1. To evaluate promising bean lines under farmers' field conditions for high grain yield and tolerance/resistance to major diseases and insects; 2. To assess the acceptability of the varieties to farmers.

MATERIALS AND METHODS

Sites and seasons

This trial was conducted for four seasons (1988/89, 1989/90, 1990/91 and 1991/92) over a range of sites which varied from year to year. During 1988/89, four Rural Development Areas (RDAs) were selected, but in 1990/91 and 1991/92 only two RDAs were selected for the trial. Co-operating farmers were selected by research assistants based in the respective RDAs. The farmers selected were those who were already growing beans. RDAs were selected so as to cover the four agro-ecological zones of Swaziland : Highveld, Middleveld, Lowveld and the Lubombo Plateau. Farmers management covers this wide range of environment.

Bean cultivars

Bean seed was provided to farmers by researchers. The produce after harvest was given back to the farmers after recording relevant data. Plot size was 2 rows x 10 m, with two replications at each site. Row spacing was on average 90cm and within row spacing was 10 cm. Bean cultivars evaluated were changed from year to year, depending on their performance. Five promising bean cultivars were chosen for on-farm testing : Carioca, BAT 1713, PVA 894, PVA 781, PVBZ 1782 and Bonus(check). This paper concentrates on the bean cultivars which were tested across the four seasons. Data collected were seedling emergence, plant stand at harvest, grain yield, visual assessment of diseases and insects, and farmers' assessment of acceptability and management.

Seed-bed preparation

A few farmers ploughed their fields in winter using either tractor or oxen, or both. Tractor ploughing tended to be concentrated on areas close to the Project Centres of the RDAs, where tractor hire pools are located. Most farmers (80%) used both oxen and tractor for ploughing, while 12% used only oxen and 8% used only tractor. Farmers start preparing the seed-bed from October to February. Tractor disking is done on fields prepared in October to mid-January. Only 10% of farmers used the tractor disk if fields were prepared in January or February, just before planting.

Planting dates

In the Highveld in Mahlangatja RDA, farmers started planting from the end of January to early March. During the study, it was found that 66% of farmers plant in February, 22% plant in January and 11% plant in early March. In the Middleveld (Southern, Central RDA; Bhekinkosi, Northern RDA), bean planting also began in January and finished in March. January planting accounted for 6%, while 82% planted in February; only 12% planted in March. This was similar to what was found in the Highveld. In the Lowveld at Mpolonjeni, the trial was conducted for only one season. Most farmers planted beans in February. Summer temperatures are very high in this zone and rainfall is erratic. Bean cultivar testing was discontinued in this zone due to the climatic conditions that prevail.

On the Lubombo Plateau at Tikhuba, the majority of farmers (70%) planted beans in February while 26% planted in March and 4% planted in January. However, during an informal survey it was found that at least 45% farmers planted two bean crops per season. The first planting is done in October/November while the second crop is planted in February/March. Bean seed quality from the early planted bean crop is poor, probably because it is harvested when there is high relative humidity and farmers have poor drying facilities (Lin, 1985; Mamba et al., 1988). It was found that farmers grow the early crop mainly to bulk seed for the main bean season (January-March), but some is also sold to neighbours (Mamba, 1991). Disease management is poor and so bulking risks spreading disease. However, it is the best method of increasing bean production since farmers usually bulk the varieties that they prefer.

Planting method

Farmers used two methods of planting. We found that 20% of farmers used an ox-drawn planter while 80% used hand methods. Planting was done when there was enough soil moisture.

The record sheets indicated that 90% of farmers plant beans in a moist, smooth seed-bed, but field observations suggest that seed-bed preparation is in fact inadequate. Improved preparation might be expected to improve plant establishment.

Fertilizer application

Farmers apply very small amounts of inorganic fertilizers, although residual fertilizer from application to maize was noted. About 75% of farmers applied fertilizer at rates varying from 50-200 kg/ha of 2:3:2. None of the farmers cooperating in the on-farm trials applied nitrogen top-dressing to their bean crop.

RESULTS AND DISCUSSION

There were large differences in the performance of the bean cultivars across the four seasons, which varied substantially in the total amount of rainfall received (Table 1). In the first season (1988/89), no significant differences were found between trial entries in the six data sets analyzed; seven of the trials were abandoned because of damage from cattle. In the 1989/90 season, three of the entries (Carioca, BAT 1713 and PVBZ 1782) significantly out-yielded the check, Bonus (Table 2). In that season, emergence and initial plant stand had been excellent but later a mortality reduced populations of all the cultivars. Bonus and PVA 894 were noted as very susceptible to rust. In the third season (1990/91) data were collected from 11/15 sites in the two RDAs of Mahlangatja and Southern at which emergence had been generally good. BAT 1713 had a significantly lower plant stand at harvest relative to other entries (Table 3), and both Carioca and PVBZ 1782 out-yielded BAT 1713 and PVA 894. All four test entries out-performed Bonus (Table 2). In the fourth season of 1991/92, only two data sets out of the twelve trials planted were collected and analyzed; most of the other trials were destroyed by drought, and a few by cattle. In the two trials, BAT 1713 and PVBZ 1782 had higher plant stands at harvest than the other two entries (Table 3). Nevertheless, Carioca significantly out-yielded the other cultivars, with a top yield of 997 kg/ha (Table 2).

Overall, Carioca was the top yielder across sites and seasons, with a mean yield of 382 kg/ha, but not significantly greater than the mean yield of PVBZ 1782 (355 kg/ha). PVA 894 was the most preferred cultivar, especially for its palatability and seed size (Tables 4 and 5), and farmers participating in the on-farm research planned to adopt both PVA 894 and BAT 1713 above other cultivars (Table 6). Farmers disliked the taste and seed colour of PVBZ 1782, nor did they like the growth habit of Carioca, BAT 1713 or Bonus, but the latter was liked for its taste. On balance, it was decided that Carioca, PVA 894 and BAT 1713 should be released to farmers. Future research should concentrate on improving plant population and cultural practices so that farmers may realize the high yield potential of these new cultivars.

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Table 1. Rainfall distribution (monthly totals, mm) over four seasons in Swaziland

Month	Years 1988/89	1989/90	1990/91	1991/92
OCTOBER	266.8	103.3	66.6	44.4
NOVEMBER	76.6	177.6	222.6	140.0
DECEMBER	216.0	97.1	189.3	120.0
JANUARY	88.0	75.1	284.5	83.1
FEBRUARY	389.4	123.1	119.1	61.7
MARCH	56.5	67.2	182.9	28.4
APRIL	27.4	39.5	0	10.0
MAY	5.2	2.0	39.2	0
TOTAL	1125.9	684.9	1104.2	487.6

Table 2. On-farm grain yield (kg/ha) of promising bean cultivars over four seasons in Swaziland

Cultivar	Season 1988/89	1989/90	1990/91	1991/92	Mean across seasons
CARIOCA	157.4	378.2a	566.2a	996.6a	381.8a
BAT 1713	121.1	362.6a	405.5b	677.7b	288.6b
PVBZ 1782	114.7	441.2a	528.8a	443.7c	355.3a
PVA 894	144.6	236.2b	393.8b	402.8c	275.8b
BONUS	-	242.0b	284.0c	-	-
Mean	134.5	332.0	435.7	630.2	325.4
SE-+	ns	25.4	26.5	39.8	14.6
C.V.(%)	55.1	35.8	28.6	26.8	30.4

Table 3. Plant stand (thousands/ha) at harvest in an on-farm bean cultivar evaluation in Swaziland.

Cultivar	Season 1988/89	1989/90	1990/91	1991/92
Carioca	53	68	57 a	82 b
BAT 1713	51	55	28 b	100 a
PVBZ 1782	55	65	63 a	92 a
PVA 894	56	49	61 a	80 b
BONUS	-	41	58 a	-
Mean	53.6	56.3	55.5	88.3
SE+_	ns	ns	2.7	3.6
C.V. (%)	16.6	22.1	16.3	17.1

Table 4. Farmers preferences for three bean cultivars to be released in Swaziland

Cultivar	Preference (%)
PVA 894	69
CARIOCA	23
BAT 1713	8

Table 5. Traits of the bean cultivar PVA 894 preferred by participating farmers

Trait	Preference (%)
Palatability	56
Seed size	56
High yield	44
Grain colour	22
Other	33

Table 6. Bean cultivars that participating farmers plan to grow in future

Cultivar	Planned adoption (%)
PVA 894	62
BAT 1713	62
Dwarf Sugar	38
Seminole	31
Carioca	15

BEAN PRODUCTION SYSTEMS ON SWAZI NATION LAND

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ABSTRACT

An informal legume survey was conducted on Swazi Nation Land in 1991. As a sequel to this study, a formal bean survey was carried out in 1992, to identify and/or verify production systems associated with bean production on Swazi Nation Land (SNL). Research procedures, including sample frame, sample size, and survey field operations are described. The interviews were conducted during the period March 9 to April 16, 1992. Descriptive statistics (averages, frequencies, and cross-tabs) were used to analyze the data. Chi-square tests were used to test difference of proportions. The results show that 60 percent of the Swazi Nation Land farmers grew beans, bush speckled sugar beans being the most commonly grown variety. The majority of the farmers grew beans in pure stands. Hand planting was the most commonly used method of planting. More than 90 percent of the bean growers applied basal fertilizers on their bean fields. However, small amounts were used. Nitrogen top dress fertilizers and pesticides were also used by the farmers, but to a limited extent. The SNL farmers identified CMR beetle (<u>Mylabris</u> spp. and (<u>Coryna</u> spp.), wilting and leaf spot symptoms as their major bean pest and disease problems, respectively. The information collected in this study will, in general, be used by the Ministry of Agriculture and Co-operatives for policy formulation and ultimately, planning purposes. The results of this study will be of particular importance to the Agricultural Research Division for the development of research involving beans. In addition, this study will form a baseline for future adoption or impact studies associated with beans.

INTRODUCTION

The common bean (*Phaseolus vulgaris* L.) is one of the major legume crops in Swaziland. It is the most important source of vegetable protein. It can also be used as a source of income. Beans rank third in terms of area under production of major crops: bean production ranges from 500 hectares on Title Deed Land (TDL) to 4200 hectares on Swazi Nation Land (SNL) (Anon, 1989). Maize, the staple food, occupies more than 70 percent of the total cropped area, followed by cotton, occupying more than 20 percent. Under dryland conditions, the common bean is grown in all the agro-ecological zones of Swaziland. However, the Lowveld has the least comparative advantage in dryland bean production. Due to their favourable climatic conditions, the Highveld, Middleveld and Lubombo Plateau have a high potential for dryland bean production. However, bean production may be constrained by soil acidity in the Highveld. The agro-ecological zones are described elsewhere (Anon, 1989; Anon, 1991; Curry, 1988; Dlamini, 1990).

Bean production is estimated at 800 metric tonnes on SNL and 1000 metric tonnes on TDL, of which 500 metric tonnes are commercial seed (Anon, 1989). Bean production on SNL is lower than on TDL. The reason for the low productivity on SNL is that, as opposed to their commercial counterparts, SNL farmers do not use yield-increasing technologies such as improved bean varieties, fertilizers and recommended plant population. Neither do they use recommended productive cultural practices, such as proper seedbed preparation, timely weeding, pest control, and crop rotation (Pali-Shikhulu, 1989; Mamba, 1990).
Lack of marketing policies may also contribute to low bean production. Unlike maize and cotton, there is no structured marketing system (marketing depots and official producer price) for beans. Therefore, farmers may not be willing to invest their resources in bean production, because they do not forsee any incentive. Currently, the Swaziland Milling Company (SMC) is the formal market for beans. However, since there is no official producer price, SMC prices fluctuate. Another reason is that the common bean is grown in the Lowveld which is not suitable for dryland bean production. As a result, the government objectives of increasing basic food crops, improving nutritional status of the rural population, and boosting rural income have not been achieved. The Agricultural Research Division (ARD) is currently developing technologies aimed at increasing crop production. Three bean varieties, namely: 1) PVA 894, 2) Carioca, and BAT 1713, have been released because they have shown an outstanding agronomic performance and have been accepted by SNL farmers (Mamba, 1992; Dlamini and Majola, 1992; Variety Release Committee, 1992).

The main objective of this study is to identify and/or verify production systems associated with bean production on Swazi Nation Land. The information collected in this study will, in general, be used by the Ministry of Agriculture and Co-operatives (MOAC) for policy formulation and ultimately, planning purposes. The results of this study will also be of particular importance to ARD for the development of research agenda involving beans. In addition, this study will form a baseline for future adoption or impact studies associated with beans.

MATERIALS AND METHODS

This section describes the sampling design and field survey methods used in this study.

Sampling design

A sample of 175 SNL legume growers was randomly chosen from Extension Workers' (EWs) list of farmers in three agro-ecological regions of Swaziland, namely: 1) Highveld, 2) Middleveld, and 3) Lubombo Plateau. These regions were chosen because they represent dryland bean production areas in the Kingdom (Mamba, 1991; Anon, 1989; Anon, 1990) and therefore, the rate of adoption of bean technologies are expected to be high. The study covers seven Rural Development Areas (RDAs), all from the above mentioned agro-ecological regions of Swaziland.

Field survey

Seven enumerators were hired and trained in data collection techniques/procedures. A pre-coded survey questionnaire designed by the author was introduced and explained to the survey team. Only a few questions were open-ended. The questionnaire was pre-tested at Motshane RDA. The main objectives of the pretest were to determine if questions were properly worded and understandable, and to evaluate the enumerators' understanding of the questionnaire. After the pre-test, the questionnaire was reviewed. Problems encountered during the pre-test were corrected.

The interviews were conducted during the period March 9 and April 16, 1992. Fields that had pure stands of the common bean were measured, using a measuring wheel and recorded on the survey questionnaire. Bean plant populations were estimated in pure stand bean fields and also recorded on the survey questionnaire. Area (in hectares) under pure stand bean production and bean plant population (plants/ha) were computed.

It was found difficult to estimate bean grain yield in the field. However, we were able to gather subjective information on bean production and homestead self-sufficiency in beans. The farmers were asked questions regarding their common bean production (15 kg-tins) in most years and self-sufficiency in this crop. This information should be used with caution because the unit of measurement (15 kg-tin or ligogogo) may not be uniform for all the homesteads.

Research Assistants (RAs) and Extension Workers (EWs) stationed at the surveyed RDAs were very helpful in introducing the survey team to the farmers. The survey operation was supervised by the author and his Research Recorder. Completed questionnaires were checked for errors in the field and in the office. Questionnaires with errors were sent back to the field for corrections. Since this was a multiple visit survey (i.e. interviews, plant population estimation and field area measurement), most of the homesteads were visited at least twice. The overall field work took approximately 2 months. The survey team was accommodated at the farmers' training centres.

Method of analysis

A minimum amount of data coding was required, since most of the questions were pre-coded. Data were entered into a micro-computer by an Encoder Operator who was hired specifically for this survey. SPSS software was used in the analysis. A Computer Programmer from the Monitoring and Evalution Unit (MEU) of MOAC gave valuable assistance during data analysis. Descriptive statistics (means, frequencies, and cross-tabs) were produced through a series of SPSS programmes. Chi-square tests were used to test differences of proportions.

RESULTS AND DISCUSSION

All analyses focus on SNL farmers who grew common beans during the 1991/92 cropping season.

Selected demographic characteristics of the sampled homesteads

Data on the demographic characteristics of the sampled SNL homesteads are presented in Table 1. More than 80 percent of the homesteads were headed by males. The average age of the homestead head was 53 years. The results regarding the characteristics of the homestead head are somewhat similar to Dlamini's (1990) findings. The results show that more than 70 percent of the homestead heads were literate and educated to the primary school level. Slightly less than 30 percent of homestead heads were employed off-farm for wages. More than 60 percent of the homesteads had members employed off-farm for wages, higher than reported by Dlamini (1990). The average number of family members employed off-farm for wages was 1.8 persons.

Bean growers

More than 90 percent of the sampled SNL farmers reported that they had at some time grown the common bean. However, 60 percent of the farmers grew the crop during the 1991/92 cropping season, as shown in Table 2, which also shows that some farmers had discountinued growing the crop, because of the severe drought which affected southern Africa.

Bean varieties

The SNL farmers were asked what bean varieties they grew during the 1991/92 cropping season. Data on bean varieties grown by the sampled SNL farmers are presented in Table 3. The findings confirm Mamba's (1991) results that the bushy speckled sugar bean is the most popular variety amongst SNL farmers. This variety was grown by 85 percent of the bean growers. Interestingly, some farmers were already growing Carioca before it was released. In her study of farmers' perceptions of the on-farm research, Malaza (1987) found that the farmers were already using the new technologies before these technologies became research recommendations. The decision to grow Carioca is also supported by the farmers' assessment of bean variety in Swaziland which indicates that farmers preferred this variety because of its high yield and palatability (Dlamini and Majola, 1992). This bean variety was released in July, 1992 (Variety Release Committee, 1992)

Management practices and production systems

Table 4 presents data on planting dates for the common bean on SNL. Most of the planting was done in February, on dates within the recommended range in the three regions. It is estimated that harvesting for late maturing varieties planted in February would take place in May.

Farmers practised both sole cropping and intercropping, however growing beans in pure stands was the more common practice, and more than 70 percent of the farmers planted the common bean in pure stands (Table 5). Mamba (1991) also found that SNL farmers practised both bean sole crop and intercropping. Of those who practised intercropping, more than 90 percent intercropped beans with maize (Table 6) and within row being the most commonly used intercropping arrangement (Table 7). The farmers planted their beans by using both ox-drawn planter and hand. However, hand planting was more widely used. More than two-thirds of the farmers planted their beans by hand (Table 8).

Basal fertilizer use on beans was common. More 90 percent of growers applied basal fertilizers to their bean fields (Table 9), and 2:3:2 (22) was the most widely used fertilizer. Other fertilizers used were 2:3:2 (38) and superphoshate. Only 17 percent of the bean growers applied nitrogen topdress fertilizer on their bean fields (Table 9); the most popular type was Limestone Ammonium Nitrate (LAN). Urea was also used by some farmers. Information regarding quantities of basal fertilizer on pure stand bean fields (Table 10) shows that only small quantities were used. The same was true of nitrogen topdressing. As also shown in Table 9, another 17 percent of the farmers had used nitrogen fertilizers in the past, but had stopped because of the severe drought during the 1991/92 cropping season. Research done on Nitrogen (N) utilization indicates that N uptake by plants is low when soil moisture is low, and it may not be economical for a farmer to apply N during a drought year (Pali-Shikhulu, et al., 1992). Another reason for stopping use was lack of money. Studies on adoption of agricultural technologies in Swaziland indicate that SNL farmers do not adopt technology because they are constrained by lack of cash (Dlamini, 1990; Dlamini, 1991; Warland, et al., 1991).

The majority of the farmers did not control pests apparently because they did not know what pesticides to use. Previous studies on Swaziland's agriculture also found that pesticide use among SNL farmers was lower than any other management practice (Dlamini, 1990; Warland et al., 1991).

More than 50 percent of the farmers use both inter-row cultivation and hand weeding methods to control weeds on their bean fields. Suprisingly, some of the farmers believe that hand weeding is not necessary on beans and that inter-row cultivation on beans is sufficient to control weeds. The explanation given for not weeding was that this crop is not affected by weed infestation. They claim that the crop produces even if it is not weeded. This means that these farmers are not aware of the yield reduction caused by weed interference. Therefore, farmers should be made aware that the common bean is also affected by weeds.

Selected agricultural characteristics of SNL farmers who grew beans on pure stands

Table 10 reports the agricultural characteristics of the SNL farmers who grew the common bean on pure stands. The average area under pure stand was 0.18 hectares. Motjane had the highest average area under bean production (Appendix A).

The average seeding rate of beans was 18.0 kg/ha. The recommended seeding rate ranges from 35 to 50 kg/ha (Anon, 1977). If farmers use the recommended rates, they can expect to achieve densities up to 220 000 plants/ha. However, the survey results show that bean plant population on SNL was one fifth of the recommended density, at an average of 42,000 plants/ha. Sandleni/Luqolweni RDA had the highest average bean plant population (Appendix B).

The results regarding the use of basal fertilizers, nitrogen topdress fertilizer, and pesticides are somewhat similar to the results presented in Table 9. More than 90 percent of the farmers who grew beans on pure stands applied basal fertilizers on their bean fields, with an average application rate of 78.6 kg/ha. This rate is only a quarter of the recommended rate of 350 kg/ha (Anon, 1977). Only 14 percent of the farmers applied nitrogen topdress fertilizers. Nitrogen topdress fertilizer applicaction was low as well, with an average rate of 34.1 kg/ha. The recommended application rate of nitrogen topdress fertilizer is about 100 kg/ha (Anon, 1977).

As shown in Appendix C, there is similarity between male and female heads of household in the use of recommended management practices. Warland and his collegues (1991) also found this. Data on adoption of recommended management practices, bean self-sufficiency and selling by each RDA are presented in Appendix D.

Sources of advice

The SNL farmers who grew the common bean and were using recommended management practices were asked who had advised them to use those practices. As shown in Table 11, the farmers most frequently reported that the Extension Worker (EWs) advised them to use basal fertilizers and pesticides. Warland and his collegues (1991) also found that farmers were advised by EWs to use fertilizers and pesticides. The farmers reported that they relied primarily on themselves for growing beans and using nitrogen topdress fertilizers.

Pests and diseases

The farmers were asked what pests and diseases attacked their common bean crop. The farmers cited the CMR beetle (*Mylabris* spp. and *Coryna* spp.) as their major pest problem (Table 12). These results support Mamba's (1991) findings.

Pest identification surveys in Swaziland indicate that the bean stem maggot (beanfly) is another major bean insect pest problem on SNL (Nsibande, 1992). However, the farmers did not report this pest. It is possible that the farmers did not observe the stem maggot because the maggots are inside the plant.

Disease identification was a problem because farmers observed symptoms without knowing the cause. Farmers observed wilting in beans and mistook it for a disease problem (Table 13). In reality, the wilting was a result of bean stem maggot attack. Leaf spot symptoms were also observed by farmers in some varieties. Research done on beans has shown that the major disease in the country is rust (*Uromyces appendiculatus*) (I.B. Kunene, pers. comm. 1992). Halo blight (*Pseudomonas syringae* pv. *phaseolicola*) and *Rhizoctonia* root rot also occur.
Research in Swaziland is focusing on identifying genotypes that are resistant to some these disease in order to complement sound cultural practices as a disease management strategy.

Production and marketing

The farmers were asked questions regarding production, self-suffiency, and marketing of beans. The results show that an average bean production on SNL is about 993 kg, but this estimate is based on the unit of measurement of 15 kg tins which may not be uniform for all homesteads.

Data on homestead bean self-sufficiency and sales are presented in Table 14. Seventy-five percent of farmers reported that they were self-suffient in bean production. Those who were not self-sufficient cited poor crop management and shortage of land as their major constraints. Lack of cash was another constraint amongst SNL farmers. Data on the relationship between research and extension activities to self-suffiency and selling are presented in Appendix E. More than 50 percent of the farmers sold their surplus beans at an average price of E3.19/kg in the informal market. At present, the informal intra-rural market is the major buyer for beans produced on SNL. As indicated earlier, SMC also buys beans, but mainly from the Republic of South Africa and TDL at an average price of E1.58/kg. As clearly shown, the formal market offers a price which is half that of the informal market. The producer is a price taker and is not protected, since there is no official produce price for beans in the country. The farmers were asked how they used the money from bean sales. As shown in Table 15, the money from bean sales was used mainly for purchasing farm equipment. Previous studies also indicate that money from crop sales is used to purchase agricultural inputs (Dlamini 1990; Warland et al., 1991). Other uses include paying school fees and buying househould items.

Farmer participation in research and extension activities

The farmers were asked questions regarding their participation in on-farm research, national maize competition, and Chinese agricultural projects. The farmers were also asked questions about their reading agricultural newsletters and listening to agricultural radio programmes. As shown in Table 16, the sampled farmers participated in different research and extension activities. More than 80 percent of the farmers reported that they listened to agricultural radio programmes. Dlamini (1990) and Warland and his collegues (1991) also reported that listening to agricultural radio programmes was popular amongst SNL farmers. The results show that agricultural radio programmmes are one of the major sources of extension information for SNL farmers. Herzog (1972) found that agricultural radio programmes had an impact on technology adoption in India and Brazil. Participation in the national maize competition and the Chinese agricultural scheme were popular amongst SNL farmers. The participation rates in these activities are higher than reported in previous studies (Dlamini, 1990; Warland et al., 1991). Warland and his collegues (1991) found that there is a significant relationship between Chinese scheme participation and self-sufficiency and selling maize. Only 16 percent reported that they had participated in on-farm research.

CONCLUSION AND RECOMMENDATIONS

The results have shown that the area under bean production is very small. Farmers reported shortage of land as one of their major constraints to bean production. The majority of the farmers grow bushy speckled sugar beans. SNL farmers produce beans mainly for home consumption. Self-sufficiency in bean production was relatively high. The results regarding the homestead self-sufficiency and bean sales show that the government objectives of increasing basic food crops and boosting rural income can be achieved, if SNL farmers can use the recommended farming practices. SNL farmers apply low rates of inputs (seed, fertilizers and pesticides) on beans. As a result of the low seeding rates, very low plant populations are achieved. Sandleni /Luqolweni RDA had the densest average bean plant population. There was a remarkable similarity between male and female heads of household and the use of most of the recommended management practices, bean self-sufficiency, and selling.

It is recommended that ARD carry out agronomic trials (different levels of plant populations and fertilizer application) using the three released bean varieties.
ARD should request assistance from SADC/CIAT to support foundation seed production. To make seed available to farmers, the Swazi-American Seed Company should play a major role in the production and promotion of the released varieties. MOAC should

continue encouraging farmers to grow beans, since this crop provides the necessary protein and can also be used as a good source of income for the rural population. In collaboration with ARD and Swazi-American Seed Company, the Extension Service should carry-out extension demonstrations on bean production in the areas of Swaziland that have a high potential for bean production. SNL farmers should be taught to identify the bean stem maggot, its symptoms of damage and how to control it. The lack of a structured marketing system for beans has been identified as one of the constraints to bean production. Therefore, the Marketing Advisory Unit (MAU) of MOAC and NAMBOARD should seek means of formalizing bean marketing.

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Table 1. Selected Demographic Characteristics of the Sampled Homesteads, 1991/92 Cropping Season (N=175)

Characteristics	Average or Percent
Male Headed Homesteads (%)	82
Female Headed Homesteads (%)	18
Age of Homestead Head (yrs)	52.9
Education of Homestead Head (%):	
a) Sebenta	6
b) Primary	44
c) Secondary	17
d) High School	3
e) College & University	3
Homestead Head Employed Off-Farm (%)	27
Homestead with Members Employed Off-Farm (%)	63
Household Members Employed Off-farm	1.8

Table 2. Percent of the Sample Farmers Who Grew Beans (N=175)

	Percent
Grew Beans	60
Dicontinued	37
Never	3

Table 3. Percent of Bean Growers by Variety (N=105).

Variety	Percent
Bushy Speckled sugar Beans	85
Carioca	5
Canadian Wonder	5
Bonus	7
Seminole	9
Contender	4
Other	6

Table 4. Planting Dates by Bean Fields (N=160)

Planting Date	Percent
October	3
November	13
December	14
January	19
February	38
March	13

Table 5. Planting Systems Used by Bean Growers (N=105)

Planting System	Percent
Sole cropped Beans	66
Intercropped Beans Only	26
Both systems	8

Table 6. Intercropping combinations used by bean growers (N=34)

Intercropping Combination	Percent
Intercropped Beans with Maize	91
Intercropped Beans with other Crops	9

Table 7. Intercropping System Used by Bean Growers (N=34)

Intercropping System	Percent
Within Rows	76
Alternate Rows	21
Other	3

Table 8. Planting Methods Used by Bean Growers (N=105)

Planting Method	Percent
Ox-Drawn Planter	31
Hand planting	69

Table 9. Management Practices Used by Bean Growers (N=105)

Practice	Current User	Discontinued	Experience
Basal Fertilizer	94	4	98
Nitrogen Topdress	17	17	34
Pesticides	15	11	26

Table 10. Selected agricultural characteristics of SNL farmers who grew beans on pure stands (N=71)

Characteristic Percent	Average or percent of SNL farmers
Bean Area (ha)	0.18
Seeding Rate (kg/ha)	18.0
Plant Population (Plants/ha)	41,553
Basal Fertilizer Use (%)	93
Basal Fert. Appl. Rate (kg/ha)	78.6
Nitrogen Use (%)	14
Nitrogen Fert. Appl. Rate (kg/ha)	34.1
Pesticides use (%)	11.4

Table 11. Sources of Advice to Use Various Management Practices (N=105)

Neighbours	Neighbours/ family	Extension worker	Other technical sources	Self
Beans	8 %	31 %	4 %	60%
Basal Fert.	6	48	3	45
Nitrogen Fert.	6	28	17	56
Pesticides	12	63	12	31

Table 12. Percent of bean growers who reported bean pests(N=105)

Pest	Percent
CMR Beetles	65
Aphids	3
Other	23

Table 13. Percent of bean growers who reported bean disease symptoms (N=105)

Disease Symptoms	Percent
Wilting	30
Leaf-spot	18
Other	19
No symptoms	33

Table 14. Percent of bean growers who reported that they were self-sufficient in beans and sold beans (N=105)

Outcome	Percent
Self-Sufficiency	75
Sold Beans	51

Table 15. How those who sell beans used the money from

Use of Money	Percent
Paid Loans	7
Bought Farm Equipment	61
Saved the Money	13
Other Uses	43

Table 16. Percent of the sample farmers who participated in selected research and extension programmes (N=175)

Programme	Percent
On-Farm Research	16
National Maize Competition	43
Chinese Scheme	46
Read Agricultural Newletters	27
Listen to Agricultural Radio	82

APPENDIX A. Area under bean production by RDA.

RDA	Area (ha)		
	Average	Standard Deviation	Maximum
Mahlalini/Madulini	0.17	0.10	0.37
Southern	0.16	0.14	0.48
Sandleni/Luqolweni	0.20	0.17	0.71
Mahlangatja	0.13	0.14	0.48
Motjane	0.24	0.25	0.25
Tikhuba	0.22	0.06	0.27
Sitsatsaweni	----	----	----

Appendix B. Bean plant population by RDA

RDA	Plant Population (no. plants/ha)		
	Average	Standard Deviation	Maximum
Mahlalini/Madulini	42618	39472	118080
Southern	47240	34399	89080
Sandleni/Luqolweni	54269	25452	98400
Mahlangatja	35996	22209	72960
Motjane	37487	27113	94800
Tikhuba	45589	43719	121600
Sitsatsaweni	-----	-----	------

Appendix C. Relationship of gender of household head and use of recommendations and outcomes

Practice or Outcome	Male Head	Female Head
Percent using basal fertiliser	92	100
Percent using topdress	16	8
Percent using pesticides	16	25
Self-sufficient	-	-
Sell beans	-	-

Appendix D. Percentage of SNL farmers who used recommended management practices, were self-sufficient in beans, and sold beans by RDA

RDA	Basal fertilizer	Topdress	Pesticides	Self Suffic.	Sell beans
Mahlalini	0	20	10	65	45
Southern	0	25	6	86	88
Sandleni	95	21	32	74	42
Mahlangantja	0	6	19	75	44
Motjane	94	29	24	71	59
Tikhuba	75	0	0	100	50
Sitsatsaweni	80	0	0	40	0

Appendix E. Relationship of research and extension activities to self-sufficiency and selling of beans

Research and Extension Activity	Self-suffic.	Not self-suffic.	Sell beans	Dont sell beans
Participated in on-farm trials	-	-	-	-
Participated in National Maize Competition	62	30a	64	46
Participated in Chinese Scheme	54	40	56	46
Read newspapers or newsletter on agriculture	31	10b	36	15a
Listen to agriculture programmes on radio	89	90	91	85a

a $P < 0.10$
b $P < 0.05$

Appendix F. Relationship of research and extension activities and use of recommended management practices

Res. and Ext. Activity	Management Practice					
	Basal Fert.		Topddress		Pesticides	
	Use	Not Use	Use	Not Use	Use	Not Use
On-Farm Trial	23	0	18	21	15	23
Maize Competition	60	0b	36	60	62	55
Chinese Scheme	53	20	36	54	39	53
Newsletters	29	60	36	30	46	27
Radio Programmes	87	80	100	84	85	87a

a $p < 0.10$
b $p < 0.05$

BEAN PRODUCTION AND POST-HARVEST SURVEY IN COMMUNAL AREAS OF ZIMBABWE

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ABSTRACT

The survey covered selected communal areas in four provinces of Zimbabwe. Beans are mainly planted in October to March and harvested from February to May. No accurate information was obtained on the specific varieties grown by farmers but the most common are Sugar beans, Michigan pea beans and Red Canadian Wonder. Beans are mainly intercropped with maize and rarely fertilized. The area under bean cultivation varied widely among the different communal households but 0.4ha seems to be the best mean area estimate. Most of the communal farmers use seed saved from previous harvests for planting while a few buy from local shops, seed companies and the Grain Marketing Board. Bean fly infestations were mentioned by some farmers to be a major problem in the early seedling stages, with Michigan pea beans being the most susceptible. In general, however, no form of disease or pest management is practised in the field. Bean yields varied widely with the cropping system (intercropping versus monocropping), variety and the level of crop management. Overall, the mean yield was estimated to be 216 kg per household (approximately equivalent to 491 kg/ha). Beans are stored in threshed form. The various storage containers used include jute bags (50kg and 91kg capacity), 20 l tins, pots (clay and metal), empty fertilizer bags, empty flour bags, small plastic and khaki bags and drums (only for beans in pod). The containers are usually kept in the granary or house. The amounts stored and sold vary depending on the yield. On average, about 20-30% of the total yield is stored. Nearly 80% of all the farmers interviewed store beans for at least six months. Bruchid damage is the major problem in storage but no meaningful estimates of losses from bruchids were obtained. Few farmers take measures to reduce bruchid infestation even though they realise their damage potential. The most common bruchid control measures used include the use of insecticides, admixing beans with ash, finger-millet husks and sand, and sunning. Smoking, alternating layers of *the leaves of eucalyptus, the weed* <u>*Tagetes minuta*</u> *(Mexican marigold) and tobacco are some of the methods used by a few farmers. Farmers believe that the effectiveness of all simple mechanical treatments range from poor (rapoko husks) to very effective (ash). They feel that the high storage losses coupled with an uncertain market have a negative impact on bean production.*

INTRODUCTION

Beans, cowpeas, groundnuts and bambarra nuts are the major grain legume crops grown in the communal areas of Zimbabwe. The growing of these crops varies from year to year, depending mainly on the availability of land and labour. They are regarded as minor or secondary crops which are grown with little or no fertilizer and do not require the use of high quality seed for planting. Yields are generally low and almost the entire produce is consumed by the farmers themselves. For beans and cowpeas, bruchid damage is the major problem which farmers face when they store their produce. Despite this, however, effective measures aimed at preventing infestation, or minimising damage, are rarely taken. Simple control methods known to most communal farmers are usually not used, because they do not give effective control. In the storage of these secondary crops, the tendency of most communal farmers is to apply control measures in response to detected infestation rather than to prevent it. Thus, timeliness of application is very important. We feel that long lasting and cost-effective bruchid control techniques may have a significant impact on bean production in the communal areas.

MATERIALS AND METHODS

The survey was conducted in fourteen districts of the country (Table 1), using a questionnaire for each household. This questionnaire was developed in collaboration with the SADC/CIAT regional bean programme. No special sampling techniques were used in selecting the farmers. Where available, samples of beans (infested and uninfested) were collected for laboratory identification of bruchid species and verification of the varieties grown.

RESULTS

The survey was mainly aimed at aspects relating to agronomy and post-harvest factors.

Planting dates

Planting dates vary among the different provinces (Table 2). With the exception of Mashonaland East, planting dates show a clear demarcation between rainy and dry seasons. The variation may not be as great as the table portrays when we take into account that the dates given by some farmers actually comprise both field- and garden-grown beans. Whereas the former are strictly grown in the rainy season, the latter are grown at any time of year: some farmers in Mashonaland East mentioned growing beans in gardens during the dry season, using irrigation from streams. Thus, all planting dates in the period April to September refer to garden-grown beans. The following planting dates are used for field-grown beans :

Mashonaland East : December-March
Mashonalnd Central : November-March
Manicaland : October-March
Masvingo : November to February.

It was also apparent that farmers living within the same village or locality use similar planting dates. This is usually done out of convenience, so that decisions of when to stop livestock from roaming free in the fields are arrived at by the community not by individuals.

Planting dates outside the range of November-February, but within the rainy season, were given mainly by farmers who plant more than once in a single growing season (Table 3). Such farmers were often from Manicaland where the first crop is planted at the end of October and the second in February to early March.

The October planting is made possible by the early onset of the rainy season in parts of Manicaland. In most of Masvingo province, the rains end early so that beans are not planted after February. The majority of farmers intercrop beans with maize; the planting date of maize appears to influence that of beans. The tendency is to plant beans when the maize crop is in the early seedling stage. The earlier maize is planted, the earlier will beans also be planted. A few farmers mentioned planting beans when the maize crop is in the tasselling or mature green cob stage, and the bean crop flowers and ripens when the maize crop has been removed (mid April onwards). However, this system is restricted to vlei soils, with a high moisture holding capacity, or where late season rainfall is prevalent. According to some communal farmers in Guruve district, the number of plantings they have of Michigan pea beans is influenced by damage due to the bean fly, or bean stem maggot, *Ophiomyia phaseoli*. They mention the maggot as the most serious pest affecting the establishment of a Michigan pea bean crop, a problem previously confused with drought stress. Other varieties are said not to be very susceptible. If infestation is very severe, the entire crop can be wiped out, leaving farmers with no option but to replant.

Harvesting dates

Harvesting dates vary widely with planting date, area (province/district) and variety. Varieties which are grown for their mature green seeds are harvested much earlier than those grown for dry seeds. The bulk of field grown beans are harvested from February-May (Table 4). Harvesting dates outside this period are of October or March-April plantings.

Varieties grown

No accurate information was obtained on the specific varieties grown, probably because farmers save their own seed year after year, so that information on the original varieties is lost. Furthermore, two or more varieties are often grown in a single field; at harvest, they are bulked, so confusing varietal identity. The most common varieties are Sugar beans, navy (Michigan pea) beans, Red Canadian Wonder and Butter beans; Topcrop and Contender are also grown but no samples were found for verification. Whatever varieties are grown, the survey revealed that most beans are grown for their fully mature dry seed. Only in very few instances were beans reported as grown for green seed or immature pods.

Arable area under beans

Area under bean cultivation varied widely among the different communal households. In Mutoko District (Mashonaland East), the survey also covered resettlement and small scale commercial farming areas which have larger tracts of arable land which can be put under bean cultivation. The wide variation in area under bean cultivation in the communal areas (Table 5) may be explained by the following:

(i) beans are usually intercropped with other crops
(ii) communal farmers usually grow beans in several small patches of land
(iii) area units are loosely defined in the communal areas.

Type of seed used and source

The kind of seed which communal farmers use as planting material has a significant bearing on the ultimate yield and the level of management which they give to the crop. Farmers give more attention to a crop from high quality seed than that from low quality. In Zimbabwe, though there is a provision for beans in the Seed Certification Scheme, this is never put into practice. What seed companies sell is what is referred to as 'standard' seed as opposed to certified seed. This is usually seed which is free from bruchid damage and often dressed with a fungicide. Varietal purity is not always guaranteed but the seed is usually of much higher quality than that kept in store by most communal farmers.

Table 6 shows that about 64% of all survey farmers obtain seed from their own stores and 42% purchase from shops, the GMB and seed companies. Farmers' Co-op (Pvt) Limited and Seed Co-op are their major suppliers. The majority cannot afford to buy from seed companies and shops, and this may help to explain why most communal farmers are content to grow beans with minimal inputs, saving seed from one year to the next and sharing among themselves any new type of seed acquired by the community.

Fertilization

Most communal farmers interviewed do not fertilize legume crops. Beans may be fertilized indirectly when farmers apply farm yard manure or basal compound fertilizers to maize, in a maize-bean intercropping system.

Disease and pest management

In the communal areas in which the survey was conducted, no form of disease or pest managment is practised. There is generally a lack of knowledge on the importance of diseases and pests. Unlike pest attack which is readily recognized, the effects of diseases are not easily appreciated and are more often confused with effects of environment such as water stress.

Yields

This was one of the most difficult aspects of the survey. Not only did yields vary greatly from household to household but also the receptacles and their capacities varied greatly, making conversion to a single unit of measurement very difficult.
Table 7 shows the mean yields of dry shelled beans per household and the mode. A full 91 kg bag is equivalent to 6 full 20 l tins. In the calculations above, 90 kg was used, thus making the weight of a full tin exactly 15kg. Of the four provinces surveyed, Masvingo had the highest mean yield and Mashonaland East the least, but the small sample sizes from Masvingo and Mashonoland East must be considered when evaluating these data. Furthermore, higher mean yield from Masvingo than from the other three provinces is unexpected, since Masvingo lies mostly in Natural Regions IV and V. The estimate of mean yield per household is 14.4 tins (approximately equivalent to 215.9 kg). Using 0.44 ha as an estimate of mean area under bean cultivation and 215.9 kg as mean yield per household, we estimate the overall average yield to be 490.6 kg/ha.

Quantities of beans sold and stored for home use

As soon as pods are fully dry, communal farmers thresh their beans, usually by beating with sticks. The threshed beans are then put into a variety of containers. Jute bags (50kg and 91kg capacity) are usually used for beans intended for sale in distant urban markets to the Grain Marketing Board or, sometimes, local boarding schools and clinics. Tins (20 litre or less), empty fertilizer and other plastic bags and pots (metal and/or clay) are usually used for beans stored for home consumption and seed saving. Beans for sale are quickly disposed of, before becoming damaged by bruchids. Table 8 shows the mean amount of beans stored for home use per household, and as a proportion of the mean yield obtained. Overall, communal farmers store slightly less than a third of their total harvest, and sell the rest.

Storage techniques

Almost all farmers store beans in threshed form; very few store them in their pods. Drums or sacks are mostly used to hold unthreshed beans. Some farmers mentioned storage of pods in sacks hung over kitchen fires, but it was also not clear whether this is intended to disinfest seeds, repel insects by the smoke or heat, or merely a to enhance drying of pods. The majority of farmers prefer to store beans in threshed form. The most commonly used containers for holding beans in storage are bags and tins. Clay pots, metal pots, small plastic and empty fertilizer bags, khaki bags and flour bags are also used.
Table 9 shows the storage containers used and Table 10 the proportion of farmers using the granary, house or other places for storage.

Length of storage

Communal farmers store beans for two main reasons: consumption at a later date, and for the next season's seed. A few others may store for later sale, often to obtain a higher price, but no case of the latter was recorded in our survey. The length of storage does not differ significantly. All beans kept for seed purposes are stored until the next rainy season, those for consumption are used up before the rainy season begins. Variation in storage time by province is shown in Table 11. In general, more than two-thirds of the farmers store beans for at least six months, typically May-December (-January).

Storage problems

Communal farmers keeping beans in storage face numerous problems such as bruchids, rodents, impaired germination and mould development. Of these, bruchid damage is much the most important (Table 12), but farmers could not give reliable estimates of the losses they incur due to bruchids.

Bruchid control in storage

The holding period, between harvest and sale, is a critical one because of the risk of bruchid damage, a situation exacerbated by the refusal of bulk buyers (e.g. GMB, National Foods Ltd., Olivine Industries) to accept treated seed. Control measures used by farmers are summarized in Table 13, and insecticide use is presented in Table 14.

The 'other' control measures include the following:

(a) alternating layers of seed with layers of finger millet husks
(b) sunning
(c) admixing seed with sand
(d) smoking
(e) use of plants or plant parts e.g the leaves of eucalyptus and *Tagetes minuta*; and
(f) alternating layers of seed with tobacco leaves

Pirimiphos methyl is the most commonly used insecticide, followed by malathion. Farmers consider it much more effective than either pirimiphos-methyl or malathion. DDT is still being used, despite its withdrawal from recommended materials.

Marketing

Soon after threshing, most farmers sell beans in excess of their needs. Some companies contract farmers to grow beans. The Grain Marketing Board (GMB) sometimes buys from farmers, especially when the Government needs beans for drought relief, but the GMB buys only in 50 kg units. Most communal farmers actually produce less than this, and the GMB cannot buy the small amounts which farmers have for sale. Furthermore, bulk grain buyers do not buy the varietal mixtures that farmers often bulk for sale.

DISCUSSION

Of the major legume crops grown in Zimbabwe, beans are grown by the least number of communal farmers. Whereas every farmer may grow cowpeas, groundnuts and bambarra nuts year after year, beans are often grown in an erratic manner. There is a tendency among farmers to intercrop beans with maize, reflecting land shortage.

The survey revealed the following main points :

(i) beans are grown with very little or no added fertilizer;
(ii) the low bean yields which most communal farmers obtain may be a result of poor quality seed used;
(iii) the risk of bruchid damage may be the major reason why farmers store small amounts of beans; and

(iv) farmers know various techniques for controlling bruchids but very few use them. This is either because they cannot afford them, that the methods do not give effective control, or that farmers do not know when to apply the measure.

(v) *Acanthoscelides obtectus* appears to be the main species.

Table 1. Areas covered by the survey

Province	District	Communal area
Mashonaland East	Mutoko	Charehwa
	"	Mutoko
	Mutoko	Chindenga
Mashonaland Central	Bindura	Musana
	"	Masembura
	Mazowe	Chiweshe
	Shamva	Madziwa
	"	Bushu
	Guruve	Chipuriro
Manicaland	Makoni	Makoni
	Mutare	Zimunya
	"	Rowa
	"	Marange North
	Mutasa	Mutasa
	Chimanimani	Chikukwa
	Chipinge	Mutize
Masvingo	Gutu	Gutu
	"	Basera
	"	Soti Source
	Bikita	Bikita
	Masvingo	Nyajena
	"	Nemamwa
	Chivi	Chivi

Table 2. Percentage of farmers planting beans at different dates

Month	Province				Mean
	Mash. E.	Mash. C.	Manicaland	Masvingo	
Jan	11.5	43.6	8.8	29.4	26.8
Feb	30.8	26.6	36.8	47.1	32.2
Mar	23.1	6.4	2.9	0.0	6.8
Apr	3.9	0.0	4.4	0.0	2.0
May	3.9	4.3	0.0	0.0	2.4
Jun	11.5	0.0	0.0	0.0	1.5
Jul	15.4	0.0	0.0	0.0	2.0
Aug	0.0	0.0	0.0	0.0	0.0
Sep	3.9	0.0	1.5	0.0	1.0
Oct	0.0	0.0	38.2	5.9	13.7
Nov	0.0	10.6	42.7	35.3	22.0
Dec	11.5	31.9	7.4	11.8	19.5

Table 3. Percentage of farmers with one or more plantings per growing season

Province	1 planting	>1 planting
Mash. East	92.3	7.7
Mash. Central	72.3	27.7
Manicaland	62.0	38.0
Masvingo	76.5	23.5
Mean	75.8	24.2

Table 4. Percentage of farmers harvesting at different dates

Month	Province			Mean
	Mash. E.	Mash. C.	Manicaland	
Jan	0.0	2.5	20.3	8.6
Feb	4.2	12.7	44.1	22.8
Mar	12.5	40.5	30.5	32.7
Apr	12.5	36.7	39.0	34.0
May	37.5	13.9	32.2	24.1
Jun	8.3	5.1	1.7	4.3
Jul	8.3	2.5	0.0	2.5
Aug	8.3	2.5	0.0	2.5
Sep	8.3	0.0	0.0	1.2
Oct	0.0	0.0	0.0	0.0
Nov	0.0	0.0	0.0	0.0
Dec	4.2	0.0	0.0	0.6

Table 5. Area under bean cultivation per household

Province*	Mean area [ha]	Mode [ha] (area given by farmers)
Mash. East	0.38 (± 0.10)	0.2
Mash. central	0.29 (± 0.07)	0.2
Manicaland	0.75 (± 0.18)	0.4
Mean	0.44 (± 0.07)	0.2

* No information obtained from Masvingo.

Table 6. Seed sources used by farmers

Province	Own & neighbours' stores (%)	Shops, seed companies & Grain Marketing Board
Mash. East	53.9	46.2
Mash. Central	55.3	54.1
Manicaland	79.4	23.8
Mean	63.8	42.0

Note: Adjacent percentages add up to more than 100 because some farmers supplement the seed from their stores with purchases from seed companies, shops or the Grain Marketing Board (GMB).

Table 7. Yields of dry threshed beans

Province	Mean yield (20 l tins)	Mode (20 l tins)	No. farmers
Mash. East	6.85 (± 2.83)	1.0	26
Mash. Central	7.90 (± 2.45)	2.0	83
Manicaland	22.40 (± 5.89)	12.0 & 18.0	68
Masvingo	27.08 (± 18.90)	12.0 & 18.0	15
Mean	14.39 (± 2.88)	2.0	192

Table 8. Amount stored for home use

Province	Mean amount stored [tins]	Proportion of yield (%)
Mash. East	1.55 (± 0.68)	22.1
Mash. Central	3.33 (± 1.25)	41.8
Manicaland	4.32 (± 0.83)	19.2
Masvingo	4.62 (± 1.76)	17.0
Mean	3.52 (± 0.62)	24.3

Table 9. Percentage of farmers storing beans in different containers

Province	Containers					
	Jute Bags	Tins	Other	Bags & tins	Bags & others	Tins & others
Mash. East	73.1	11.5	11.5	0.0	3.9	0.0
Mash. Central	84.0	3.7	11.1	1.2	0.0	0.0
Manicaland	79.3	0.0	20.7	0.0	0.0	0.0
Masvingo	70.6	0.0	23.5	0.0	5.9	0.0
Mean	79.7	3.3	15.4	0.5	1.1	0.0

Table 10. Percentage of farmers using different places for storage

Province	Granary	House	Other*
Mash. East	26.9	73.1	0.0
Mash. Central	72.9	25.9	1.2
Manicaland	89.7	8.6	1.7
Masvingo	64.6	17.7	17.7
Mean	70.9	26.4	2.7

* Kitchen, store room, cribs and shed.

Table 11. Percentage of farmers storing beans for different periods

Province	< 2 months	2-5 months	> 6 months
Mash. East	20.0	4.0	76.0
Mash. Central	6.2	17.3	76.5
Manicaland	1.7	6.9	91.4
Masvingo	41.2	23.5	35.3
Mean	9.9	12.7	77.4

Table 12. Storage problems faced by farmers (%) *

Province	Bruchids	Rodents	Moulds	Moisture	None
Mash. East	65.4	23.1	15.4	19.2	34.6
Mash. Central	34.6	3.7	0.0	0.0	65.4
Manicaland	58.8	5.9	11.8	11.8	35.3
Masvingo	94.1	76.5	29.4	5.9	5.9

* Adjacent percentages add up to more than 100 because some farmers have more than one problem in storage.

Table 13. Percentage of farmers using different bruchid control methods

Method	Province				Mean
	Mash. E.	Mash. C.	Manicaland	Masvingo	
P-methyl	34.6	14.8	53.5	70.5	43.4
Malathion	3.8	17.3	8.6	11.8	10.4
Methacrifos	3.8	1.2	1.7	0.0	1.7
DDT	0.0	0.0	1.7	11.8	3.4
Unknown chemical	0.0	0.0	1.7	5.9	1.9
Ash	3.8	6.2	3.4	0.0	3.4
Finger-millet husks	0.0	1.2	0.0	0.0	0.3
Other	0.0	3.7	8.6	0.0	3.1
None	54.0	55.6	20.8	0.0	32.6

Table 14. Percentage of farmers using insecticides

Mash. East	42.3
Mash. Central	33.3
Manicaland	65.5
Masvingo	100
Mean	51.1

DISCUSSION OF THE ON-FARM RESEARCH SESSION'S PAPERS

Lupwayi: Can Dr. Edje elaborate on the system of seed distribution used ?

Edje : We are trying a new approach that accelerates farmer's access to new varieties, by distributing small quantities (1-10 kg) of seed to farmers, with a follow-up survey to see what those farmers have done with that seed. A limitation was the logistical difficulty of retrieval of the amount of seed initially given.

Teri : Did you do economic analyses in support of exploratory trials ?

Edje : No, because this was not the objective of this series of trials, which were designed solely to be diagnostic.

Lana : With regard to Usambara Mottle, did you track down the macro or micro-element responsible for this problem ?

Edje : Yes, it is potash deficiency.

Mushi : I am concerned about the sustainability of the system of OFR described.

Arias : How applicable is your approach to intercropping ?

Edje : I hope I didn't give the impression that our work has been conducted in monoculture. Farmers have a choice; most trials were run in crop association.

Aggarwal : Do we really know whether farmers really do want new technologies ? Small-scale farmers have little incentive to adopt new technologies, and our efforts should instead be aimed at governments. With political will, new technologies can make spectacular change.

Bosch : I disagree. Farmers do have interest in new technologies. But I do agree that not all constraints are technological.

Nahdy : Where infrastructure is good, then farmers can respond through an interest in trade. In Uganda, things are changing with liberalization of trade.

Mitti : I think you are running away from the issue of household food security !

Edje : We need to identify points of leverage where we scientists can make impact. Let's try to help the farmer now, not waiting until everything else is in place.

Aggarwal : I am suggesting that there is a lack of political will. Agriculture is the backbone of development in most countries !

Lana : What is the altitude of Kagera ? Is it suitable for SUA 90 ? Why don't you include it in your trials ?

Mushi : I don't think SUA 90 should be included, for now. It is liable to prove susceptible to anthracnose.

Mukoko : It is interesting that, in Mitti's presentation, it was reported that climbing types were found to be commoner than expected. Are these true climbers or merely indeterminate bush types ?

Mitti : We are not yet sure.

Mukoko : This needs clarification as it has important implications for breeding.

Teri : Bosch, you said that you are now improving the local varieties. What does this mean ?

Bosch : We are not breeding. We do need to look for better small white-seeded types.

Mkandawire : Bosch, your data showed large effects of season, and of on-station versus on-farm conditions. What can be done ?

Bosch : The introduction of bananas does not itself improve soil. There are large differences in soil between "kibanja" and "rweya" soils in Kagera.

Lupwayi : Farmers often underestimate the importance of diseases. Does Mitti believe they are unimportant ?

Mitti : Farmers usually cannot articulate well over pests and diseases, but I do not believe diseases are unimportant.

Lana : I want to return to this. Can farmers identify pest and disease problems sufficiently even to respond to a questionnaire on their importance ?

Edje : It is important to make inferences from farmer surveys, but the Teri and Mohamed approach of showing samples may help.

Mitti : In the second crop in Zambia, disease pressure is less.

Lana : But insect pressures can be heavier in a late (Feb) sown planting, surely ?

Ampofo : Pest damage is often greater when plants are under stress.

Nahdy : Why do you think that leaves fall off during the long rains in Kagera ? Is it due to disease, or some other factor ?

Bosch : Our observation is that it is not due to disease but to some effect in the root zone during periods of very heavy rain, perhaps including impeded drainage, and radiation.

Giga : Why do people grow beans in such heavy rainfall areas ?

Bosch : Farmers are not growing beans at that time of year in Kagera.

Mushi : There may be opportunities for introduction of climbing types for the long rains season in Kagera.

Allen : Giga's data on Masvingo seem anomalous, in that it is the area of the greatest use of insecticide, the shortest period of storage, and yet the greatest bruchid problems.

Giga : Agreed.

Nahdy : Other surveys have also shown that heavy insecticide use and farmer perception of the importance of bruchids does not always make sense.

Aggarwal : Problems are expected to be greater in drier areas, like Masvingo, surely ?

Giga : Yes, but back to Allen's comment, I would not place much confidence on the Masvingo data, as the sample size was rather small.

Aggarwal : Mamba, the mean yields of your varieties now released seem inversely proportional to their acceptability. Why do you want to release them ?

Mamba : Data on their yield stability indicate their superiority over Bonus. We want to give farmers an alternative.

Bosch : What plant stand were you aiming at in your trials ? These seem low, and yet stand may be more important than variety.

Mamba : Farmers dislike narrow row spacings.

Youngquist : There are several important points here. One is that there are many different environments and many different systems. It is important not to restrain the farmer. They need a wider choice.

Mushi : The problem is seed.

Edje : Yes, especially if reliance is placed on conventional channels of seed production. Seed companies often oppose release of multiple varieties.

Mitti : Can we release mixtures ?

Edje : Probably not.

Allen : In countries were varietal mixtures are important, including Rwanda, farmers grow newly released varieties in monoculture to assess them. If they like them, they are then incorporated into their mixtures.

Teri : Mamba, is the seed company planning to multiply varieties?

Mamba : They are involved in seed release.

Edje : Why are your yields so low ?

Mamba : These yields were obtained merely under farmer management.

Mitti : But why so low ?

Mamba : Germination was poor, apparently because of poor seed bed preparation, and also from poor weeding.

Teri : In Dlamini's paper reference is made to a wilt. Could it be *Pseudomonas* wilt or is it bean stem maggot ?

Mamba : We are not sure.

SESSION 3 : AGRONOMY

SADC/CIAT REGIONAL DROUGHT SUB-PROJECT ON BEANS, *Phaseolus vulgaris*

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ABSTRACT

Experiments were conducted in three years to identify and evaluate available bush bean germplasm for greater tolerance and adaptability to drought stress. Bean accessions from our germplasm and that imported from North and South America, South Africa and other parts of Africa were used under both irrigation and phased-planting situations. Results indicate that drought tolerance characteristics in beans are mainly those that relate to canopy size, biomass and leaf area. Leaf moisture retention capacity was negatively associated with seed yield. Drought tolerant bean materials maintained the number of pods per plant and seed size under stress, as opposed to those that are susceptible. Some of the bean materials from our germplasm were moderately tolerant to drought stress. In general, the small-seeded materials were more drought tolerant than the large-seeded types. There may be a requirement to cross small and large-seeded types to transfer drought tolerance. The roots may be playing a central role in drought tolerance by mining more soil moisture to effect the larger changes in canopy characteristics observed in drought tolerant genotypes. The African Bean Drought Resistance Evaluation Nursery (ABDREN) was conducted in several countries. The evaluation showed that G 5201, BAT 798 and BAT 1198 from CIAT gave good yields across locations. This may indicate these materials may be used as parents in crossing blocks in the breeding component of the regional drought sub-project. A more complete data set is being analyzed in collaboration with the Eastern Africa Regional Bean Programme.

INTRODUCTION

The common bean *(Phaseolus vulgaris* L.) is a major food crop and one of the main sources of protein for inhabitants of tropical and sub-tropical regions of the world. Beans are one of the most important food legume crops in Malawi. As food, they provide proteins, vitamins A and C, and they are also a good source of energy, providing comparable values of calories as maize, milled rice or cassava flour. Beans surplus to home requirements are usually sold; there is high demand for domestic consumption and there is a good export market. The beans most commonly eaten are dry beans which are red, white or colour variegations. They are cooked and eaten as relish with *nsima*. Apart from being food and a source of income, beans are also replenishers of soil fertility through nitrogen fixation.

Beans originated in the Andean region (Peru, Bolivia and Colombia) in South America and the Meso-American region (Mexico) in Central America. They have been grown in Malawi for more than 300 years. As a result of Malawi's ecological, geographical and cultural diversity, the original bean introductions have evolved with gross morphological variation in terms of growth habit, seed size, colour and shape, among many other characters. Unfortunately, yields of beans are low, partly due to a lack of suitable cultivars that are resistant to diseases, pests, low moisture conditions and a general lack of improved cultural practices. One way of increasing national levels of bean production would be to identify moisture-tolerant cultivars for growing during the ordinary rainy seasons where stress can occur intermittently, or during other times when a bean crop can be successfully grown on residual moisture under terminal stress.

Crop plants, including the common bean, rarely attain their full genetic potential for yield due to limitations imposed by the environment, such as extreme temperatures and shortage of water. It is believed that about a third of world's potentially arable land suffers from an inadequate supply of water and, on most of the remainder, crop yields are periodically reduced by moisture-stress. Plant water deficits affect every aspect of plant growth and the world-wide losses in yield from stress probably exceed the losses from all other causes combined.

The objectives of the work described in this paper were to identify and evaluate available bush bean germplasm for greater tolerance and adaptability to drought stress, and to provide information on the developmental and physiological processes enabling greater tolerance and adaptability to drought. To attain these objectives, a number of experiments have been conducted at Bunda College, Lifuwu, and Kasinthula Research Stations in Malawi. These experiments are described and discussed separately.

MATERIALS AND METHODS

Drought tolerance mechanisms

Experiment 1. Performance of bush bean genotypes under controlled drought stress conditions.

One experiment was planted at Kasinthula Agricultural Research Station on 22 June, 1989 and another at Bunda on 25 June, 1991. Twenty-five genotypes of bush beans including Malawian landraces and introductions from North and South America, and South Africa, (Table 1), were used in a split-plot design with three replications. The mainplots were :

a. Adequate irrigation throughout growth cycle;
b. Drought stress imposed during flowering;
c. Drought stress imposed during pod-filling.

Drought was imposed by stopping irrigation a week before the start of the respective growth stages. The genotypes were sub-plots. Each sub-plot was comprised of 4 ridges (spaced 0.60 m apart) apart and 5m long. Beans were planted at a spacing of 10cm intra-row. A fertilizer mixture (23:21:0 + 4 of N:P:K: + S) was applied before planting at 200 kg/ha, using the banding method. The data collected were bean seed yield and its components, phenological characteristics and canopy size. The latter was obtained by using a graduated cross that is placed at the centre of the row and then the width and height of the canopy are each read from it.

Experiment 2. Performance of bush bean genotypes under terminal moisture-stress conditions.

The experiment was planted at Bunda on 15 March, 1990 and 1991 with three replications in a randomized complete block design. Fifteen genotypes were used : Malawian landraces 3-14, 25-2 x 8 -7, 2-10 x 8 -7, 6-1, 8-7, 25-2, 2-10, 5-2, Nasaka and Sapelekedwa; and introductions Majuba (ex South Africa), C-20 (ex USA) and the CIAT lines BAT 336, BAT 85 and BAT 125. Each plot comprised four ridges spaced 0.9m apart and 5m long. A fertilizer mixture (23:21:0 + 4 of N:P:K + S) was applied at 200 kg/ha by banding just before planting. Leaf area index was measured at 8 weeks after planting and leaf expansion was measured 3-4 weeks from planting. Leaf moisture retention capacity (LMRC) was measured as was canopy height. LMRC was obtained by removing two leaves from two plants and weighing them immediately. The leaves were then hung on a wire at room temperature for 48h. They were then re-weighed and then oven-dried for 48h at 80C. The amount of moisture retained by the leaves during air-drying was obtained by subtraction and expressed as per cent total leaf water content. Yield and yield components were measured. The rate of soil moisture depletion was determined by measuring soil water content gravimetrically (Fig. 1).

Experiment 3. Physiology of moisture stress tolerance in beans

This experiment was conducted under irrigation at Bunda College during the dry seasons of 1990 and 1991. A split plot design was used. Two main-plots were included : well-watered throughout the growth cycle; and drought stress imposed from V3 (third trifoliolate stage). The well-watered plots were irrigated once every week. Eight sub-plots consisting of cultivars were used. The four tolerant genotypes were : Sapelekedwa, BAT 336, 6-5, and Nuweveld whereas the susceptible ones were 16-6, BAT 125, 1-1, and Kamberg.

The main-plots were separated by a 1m path and replicates were separated by a 2m path. Each sub-plot consisted of 4 ridges of 4m each and 0.6m inter-row spacing. A fertilizer mixture (23:21:0 + 4 of N:P:K + S) was banded at the rate of 200 kg/ha. Soon after fertilizer application, beans were planted at 10cm intra-row spacing, with one seed/station.

African bean drought resistance evaluation nursery

The African Bean Drought Resistance Evaluation Nursery (ABDREN) is the second component of the SADC/CIAT Regional Drought Sub-Project. The objectives of the ABDREN are : a) To evaluate the performance of promising bean cultivars identified under drought conditions in Ethiopia and Latin America, and across a wide range of African dry environments ; b) to develop further a regional testing network for beans in Africa; and c) to examine and interpret genotypic responses of different patterns of drought in selected bean cultivars.

The trial design used was a 4x4 triple lattice, involving fifteen materials and the local check (Table 2) with three replications. Each plot comprised 4 rows of 4m each. Crop management and spacing followed local practice. The following plant characters were measured :

Date of emergence
Stand count
Plant height
Date of first flowering
Date to maturity
Number of pods/plant
100-seed weight
Disease and insect scores
Seed yield

RESULTS

Drought tolerance mechanisms

Experiment 1.

At Kasinthula, the 25 genotypes did not differ across moisture regimes, in the time taken to reach flowering (Table 3). This was because treatments had not been imposed up to a week before flowering. However, the period of time to the end of flowering was significantly reduced when drought was imposed during flowering. This caused a significant reduction in duration of the flowering period under such moisture-stress conditions. This difference was maintained up to physiological maturity. Growth rates apparently were reduced by moisture stress at flowering, as suggested by significant reduction in both canopy height and width, and per cent canopy cover at the R6 stage of development. The number of pods/plant was significantly reduced by moisture-stress imposed either at flowering or during pod-filling. The reduction in number of pods when drought was imposed during flowering was most probably due to fewer flowers setting as a result of pod abortion. However, 100-seed weight was significantly reduced only by moisture-stress at pod-filling. The number of seed/pod did not differ in bean genotypes across moisture regimes. Seed yields were significantly reduced by moisture-stress at either flowering (70%) or pod-filling (76%) (Table 3). Both stages seemed to be equally important for moisture-stress to significantly affect seed yield obtained. The reduction at the former stage was probably more a result of reduction in number of pods/plant, whereas the reduction at the latter stage was a result of reduction in 100-seed weight. Drought susceptibility indices were calculated following Fischer and Maurer (1978). Tolerant genotypes at flowering were Sapelekedwa, BAT 125, BAT 336, Domino, A 268, 8-7, 25-2, and PVA 894 (Table 4). When drought was imposed at pod-filling, tolerant genotypes were Sapelekedwa, A 442, 8-7, ICA 21148, 25-2x8-7, 2-10x8-7, A 344, and PVA 1095.

Similar data were obtained at Bunda during the dry season of 1991 and are now partially analyzed statistically. Stem weight, 100-seed weight, pod length, pods/plot and seed yield were all significantly reduced due to drought either at flowering and/or at pod-filling stages (Table 3). Cultivars also significantly differed in these characteristics, including seeds/pod. Across water regimes BAT 1386 and 2-10x8-7 were the best varieties (yields > 1200 kg/ha), perhaps mainly due to their yield potential under non-stress conditions. However, BAT 1386 did not give particulary good yields under stress. Sapelekedwa and PVA 1095 gave fairly good yields under drought stress. Majuba was relatively unresponsive. An interesting observation is the general lack of significant interaction between drought stress and genotypes. This may suggest that the genotypes used do not perform differently under various soil moisture regimes. Consequently, it may be possible to make selections of tolerant genotypes in the absence of any stress.

Experiment 2 :

Seed yields of the fifteen bean genotypes are shown in Table 5. Genotypes differed significantly in yielding ability under terminal drought conditions. The highest yielding genotypes were of the small seeded types from CIAT and the USA. The same genotypes produced greater leafage than those that performed poorly (Table 5). However, it seems that the poor genotypes were able to retain more moisture in the leaves when exposed to the atmosphere than the tolerant genotypes (Table 6). Canopy height at 57 days after planting (DAP) also showed the general trend observed with yields.

Correlation analysis (Table 7) indicates that LAI, canopy characteristics and number of pods/m^2 are strong indicators of yielding ability under these conditions. However, LMRC is another strong indicator but it is negatively associated with yield.

Experiment 3 :

Sapelekedwa, BAT 336, BAT 125, and 6-5 accumulated more root biomass than the other genotypes under well-watered conditions. These genotypes also had more root biomass under moisture-stress (Table 8). The stem biomass of Sapelekedwa, 1-1, 6-5, and BAT 336 were above the mean of 18.3 g/m^2 in the well-watered plots while the same genotypes, including BAT 125, had more biomass than other genotypes. Leaf area indices of the genotypes Sapelekedwa, 1-1. 6-5 and BAT 336 in the well-watered plots were relatively high and the same varieties in the stressed plots including Nuweveld had higher leaf area indices than the rest of the varieties. Similar data were obtained at 78 and 92 DAP. At 78 DAP, three of the four tolerant genotypes (Sapelekedwa, 6-5, and Nuweveld) had above average canopy height in the well-watered plots.

Seed yields at the end of the experiment were significantly different between the well-watered and drought-stressed treatments (Table 9). The mean yield under good moisture conditions was 1376 kg/ha whereas under drought stress it was 174 kg/ha. The drought tolerant genotypes had significantly greater yields especially under stress conditions, than the susceptible genotypes. One reason for their higher yields was a smaller decrease in number of pods/plat and seed size under stress, especially in Sapelekedwa and Nuweveld. Similar data were obtained during 1991 (Tables 10 and 11).

AFRICAN BEAN DROUGHT RESISTANCE EVALUATION NURSERY

The results of the ABDREN in the SADC region are presented in Figs. 2-5. Better materials across the board relative to the checks included G 5201, BAT 798 and 1198. BAT 477, an established drought tolerant genotype under Palmira conditions, performed well under Lifuwu, Malawi and Selian, Tanzania, only. From other work it is apparent that drought tolerance is in small-seeded materials and results from ABDREN confirm that assertion. This may point to the fact that G 5201, bat 798, and BAT 1198 may further be used in crosses for drought tolerance. Unfortunately, experience from elsewhere indicated that transfer of genes, throught crossing, between such small-seeded materials of Meso-American gene pool to the large-seeded preferred materials of Andean origin is difficult. This is a fact that will need consideration by the Breeding Component within this Sub-Project. The variety AND 197 is fairly large-seeded and would be preferred in the SADC region and it is as early as the local checks.

ACKNOWLEDGEMENT

The work reported here is part of collaborative research conducted more widely within the SADC region, involving the input also of other scientists including K. Kanenga (Msekera Research Station, Chipata, Zambia), T. Nleya (Harare Research Station, Zimbabwe) and C.S. Mushi (Lyamungu Research Station, Moshi, Tanzania) whose cooperation is acknowledged.

REFERENCE

Fischer, R.A. and R. Maurer (1978). Drought resistance in spring wheat cultivars. I. Grain yield responses. Aust. J. Agric. Res. 29, 897-912.

Table 1. Twenty-five genotypes used in Experiment 1 at Kasinthula and Bunda, Malawi.

Genotype	Origin	Seed Colour
Sapelekedwa	Malawi	red
Diacol Calima	Colombia	speckled red
BAT 1387	CIAT	speckled red
BAT 125	CIAT	cream
BAT 336	CIAT	cream
BAT 477	CIAT	cream
BAT 1386	CIAT	speckled red
C-20	USA	white
Domino	USA	black
A 268	CIAT	cream
A 286	CIAT	cream w/stripes
A 442	CIAT	cream
Bonus	South Africa	cream sugar
8-7	Malawi	purple
ICA 21148	Colombia	speckled red
25-2	Malawi	white (red hilum)
25-2x8-7	Malawi	red
2-10x8-7	Malawi	white
Nasaka	Malawi	khaki
Majuba	South Africa	yellow
Umvoti	South Africa	cream sugar
A 344	CIAT	cream
PVA 894	CIAT	speckled red
PVA 781	CIAT	speckled red
PVA 1095	CIAT	red

Table 2. Sources of African Bean Drought Resistance Evaluation Nursery (ABDREN) materials

Variety	Source (origin)	Seed size (g/100)	Plant ht. (cm)
A 152	CIAT	29	63
EMP 105	CIAT	27	59
G 4830	Brazil	24	66
G 5201	Mexico	26	58
G 5059	Brazil	34	59
G 4446	Mexico	33	49
V 8025	Brazil	30	62
AND 197	CIAT	51	70
BAT 477	CIAT	39	38
BAT 798	CIAT	29	60
BAT 125	CIAT	28	34
BAT 1198	CIAT	25	70
BAT 338-1C	CIAT	27	48
Ex-Rico 23	Colombia	28	82
Mexican 142	Mexico	25	60
Sapelekedwa	Malawi	46	49

Table 3. The effect of three water regimes on a number of characteristics of twenty-five bean genotypes.

Characteristic	Water regime WW	DSF	DSPF	Prob.
		1989		
Start of flowering (d)	45.8	45.8	45.3	NS
End of flowering (d)	65.4	65.1	64.2	*
Duration of flowering	25.9	26.0	24.9	**
Physiological maturity	77.0	77.4	75.6	*
Canopy cover (%)	78.1	68.7	75,2	*
Canopy height (cm) R6	47.5	43.0	47.7	**
Canopy width (cm) R6	47.0	41.9	44.0	*
Pods/plant	15.0	13.0	12.6	**
Pod length (cm)	11.1	10.7	10.9	*
Seeds/pod	4.9	4.7	4.8	NS
100-seed weight (g)	35.7	36.1	31.3	**
Seed yield (kg.ha)	1000	697	760	*
		1991		
Stem weight (g/plot)	31.3	19.0	24.1	**
Seeds/pod	44.8	44.0	44.1	NS
100-seed weight (g)	32.7	33.6	25.6	**
Pod length (cm)	10.8	10.1	10.3	**
Pods/plot	106	80	81	**
Seed yield	1173	755	505	**

WW = well-watered
DSF = drought-stress at flowering
DSPF = drought-stress at pod-filling

Table 4. Drought susceptibility indices (S) of twenty-five bean genotypes, Kasinthula, 1989.

Genotype	S at flowering	S at pod-filling
Sapelekedwa	0.707	0.223
Diacol Calima	1.210	0.972
BAT 1387	1.339	2.784
BAT 125	0.706	1.390
BAT 336	0.835	2.215
BAT 477	0.338	0.217
BAT 1386	1.975	2.261
C-20	1.151	2.568
Domino	0.483	1.250
A 268	0.349	3.469
A 286	1.154	0.425
A 442	1.345	0.208
Bonus	1.624	1.542
8-7	0.783	0.699
ICA 21148	1.068	0.449
25-2	0.970	0.998
25-2x8-7	1.375	0.378
2-10x8-7	1.070	0.828
Nasaka	1.294	1.363
Majuba	1.371	2.261
Umvoti	1.504	1.521
A 344	1.014	0.878
PVA 894	0.767	2.024
PVA 781	1.553	2.012
PVA 1095	2.184	0.491

Table 5. Yield* and yield components of fifteen genotypes phase-planted in 1990.

Genotype	Yield kg/ha	Pods/m^2	Seeds /pod	Pod length (cm)
BAT 85	1110a	105a	6.23a	10.9cd
BAT 336	1016ab	122a	5.47b	12.2a
C-20	763b	118a	4.80bc	9.3ef
BAT 125	484c	55b	4.90bc	9.9e
3-13	449c	54b	3.57def	9.9e
Nasaka	413c	53b	3.17ef	11.8abc
8-7	410c	51bc	3.07ef	10.1de
6-1	379c	49bc	3.57def	11.2abc
2-10x8-7	359cd	48bc	3.47def	12.1a
25-2x8-7	328cd	43bc	3.40def	11.4abc
5-2	328cd	45bc	3.63def	8.6f
Sapelekedwa	322cd	50bc	2.87f	11.0bcd
25-2	268cd	40bc	4.17cd	12.0ab
2-10	255cd	57b	3.00f	11.1a-d
Majuba	70d	21c	3.90de	8.6f
Mean	464	61	3.95	10.7
LSD (p<0.05)	256	27	0.76	0.94
CV (%)	33.1	26.2	11.5	5.23

* Means followed by the same letter are not significantly (P<0.05) different, Duncan's Multiple Range Test.

Table 6. Leaf area index (LAI)*, leaf moisture retention capacity (LMRC), canopy height (CH) and canopy width (CW) at 57 DAP (1990).

Genotype	LAI	LMRC (%)	LE (cm^2/d)	CH (cm)	CW
BAT 85	3.96a	16.3cd	7.56a	85.7c	51.0ab
C-20	3.67a	9.6d	5.29abc	90.bc	53.7a
BAT 336	3.07ab	24.8abc	5.88abc	82.3c	48.3abc
BAT 125	3.04ab	17.8bcd	6.69ab	105.0ab	43.0bcd
8-7	2.10bc	36.4a	3.98abc	47.3ef	37.0de
2-10	2.08bc	33.2a	4.77abc	55.3de	35.7de
Sapelekedwa	2.08bc	25.2abc	2.85bc	44.0ef	41.3cd
2-10x8-7	2.05bc	30.1ab	4.36abc	104.7ab	35.3de
25-2x8-7	1.98bc	31.6ab	4.03abc	108.3a	38.0de
3-13	1.89bc	39.3a	4.18abc	91.7bc	37.7de
5-2	1.79bc	34.2a	2.95bc	65.3d	33.0de
6-1	1.73bc	25.0abc	2.69c	41.3ef	35.0de
25-2	1.38c	32.3a	4.48abc	44.3ef	35.3de
Nasaka	1.26c	37.4a	4.38abc	46.0ef	39.0cd
Majuba	1.07c	38.2a	6.46abc	32.7f	28.0e
Mean	2.21	28.8	4.70	69.6	39.4
LSD ($p<0.05$)	1.27	12.3	3.34	15.2	8.8
CV (%)	34.4	25.5	42.5	13.0	13.3

* Means followed by the same letter are not significantly ($P<0.05$) different, Duncan Multiple Range Test.

Table 7. Correlation coefficients (r) of growth parameters with seed yield (1990).

Growth parameter		
Leaf area indes (LAI)	0.658	$p<0.05$
Leaf moisture retention (LMRC)	-0.505	$p<0.05$
Pod lenght (cm)	0.185	NS
Pods/m^2	0.857	$p<0.05$
Seeds/pod	0.694	$p<0.05$
Canopy height (cm) at 57 DAP	0.406	$p<0.05$
Canopy width (cm) at 57 DAP	0.770	$p<0.05$
Leaf expansion (cm^2/d) at 47 DAP	0.276	NS

Table 8. Total biomass and its components and LAI at 64 days after planting, 1990.

Genotype	Roots (g/m^2)		Stems (g/m^2)		Total (g/m^2)		LAI	
	WW	MS	WW	MS	WW	MS	WW	MS
Sapelekedwa	12.0	3.8	27.5	7.1	87.5	25.2	1.17	0.46
BAT 336	11.1	2.6	18.4	7.7	68.2	27.7	1.34	0.43
6-5	8.7	2.7	25.6	8.9	83.5	27.2	1.67	0.42
Nuweveld	4.4	1.4	13.0	5.5	46.4	20.2	1.00	0.40
16-6	5.7	1.3	9.9	4.2	38.0	13.0	0.48	0.24
BAT 125	10.3	2.9	13.5	7.4	56.1	24.0	1.09	0.38
1-1	7.8	2.4	26.9	8.0	85.4	25.2	2.08	0.48
Kamberg	6.5	1.8	11.4	3.9	40.1	15.3	0.76	0.23
Mean	8.3	2.4	18.3	6.6	63.2	22.3	1.20	0.38
SE	0.83		1.82		4.58			0.08

Table 9. Yield and yield components of eight bean genotypes grown under different water regimes, 1990.

	Yield (kg/ha)		Pods/plant		Seeds/pod		100-seed wt.	
	WW	MS	WW	MS	WW	MS	WW	MS
Sapelekedwa	1255	269	14	6	4	4	46.2	33.2
BAT 336	1494	191	22	7	6	5	19.2	12.9
6-5	1687	231	17	6	6	4	24.2	20.0
Nuweveld	1815	366	23	11	7	7	19.4	15.1
16-6	848	87	12	3	4	3	34.7	24.8
BAT 125	1583	75	22	4	5	3	19.1	12.8
1-1	783	-	22	-	5	-	22.8	-
Kamberg	1536	173	34	10	6	5	14.1	10.3
Mean	1376	174	21	6	6	4	25.0	16.2
SE	91.6		16.3		2.3		8.8	

WW : well watered
MS : moisture-stressed

Table 10. Seed yield, 100 seed weight and pods/plant of eight bean varieties under two moisture regimes.

	Seed yield(kg/ha)		100 seed wt.		pods/plant	
Variety	WW	MS	WW	MS	WW	MS
Sapelekedwa	1610	709	45	47	16	12
BAT 477	1539	1199	23	22	18	17
6-5	1655	1112	24	27	27	15
Nuweveld	2808	1115	24	24	40	19
16-6	748	327	36	32	14	14
BAT 125	1335	954	23	21	30	24
13-3	1667	664	42	41	23	22
Kamberg	542	252	25	17	25	18
Mean	1490.5	791.5	30	29	24	18
Grand mean	1141.00		29.60		20.85	
CV %	34.99		18.23		33.69	
LSD (5%)	498.20		11.13		2.72	

WW : well watered
MS : moisture stressed

Table 11. Biomass and leaf area index of eight bean varieties[1] under two moisture regimes 84 days after planting.

	Root g/m		Stem g/m²		Leaf g/m²		Pod g/m²		LAI g/m²	
	WW	MS	WW	MS	WW	MS	WW	MS	WW	MS
1.	6.8	4.4	21.7	11.0	37.1	25.6	86.0	41.6	0.8	0.5
2.	5.1	2.7	27.2	16.9	68.7	29.1	21.4	29.2	2.5	0.5
3.	6.5	3.8	45.3	23.9	78.6	36.9	62.3	54.9	2.3	0.8
4.	4.0	3.4	59.0	25.6	116.9	51.0	69.8	35.6	3.0	1.4
5.	6.3	3.9	19.9	15.6	19.9	15.6	65.4	40.6	1.9	0.9
6.	13.0	6.7	72.9	54.8	72.9	54.8	16.1	18.5	3.0	2.3
7.	4.1	2.8	34.3	20.1	53.6	25.6	77.2	47.3	1.2	0.6
8.	8.1	5.7	34.2	23.5	85.3	37.9	11.8	21.0	2.3	1.1
Mean	6.7	4.2	39.3	23.9	73.2	34.4	51.4	36.1	2.1	0.9
G. mean	5.5		31.6		53.8		43.7		1.6	
CV%	29.3		25.8		21.4		52.0		46.9	
LSD(5%)	0.9		5.3		16.5		50.2		0.9	

[1] Key for table, varieties :

1. Sapelekedwa
2. BAT 477
3. 6-5
4. Nuweveld
5. 16-6
6. BAT 125
7. 13-3
8. Kamberg

Figure 1: Soil moisture at 10 cm depth under two moisture regimes

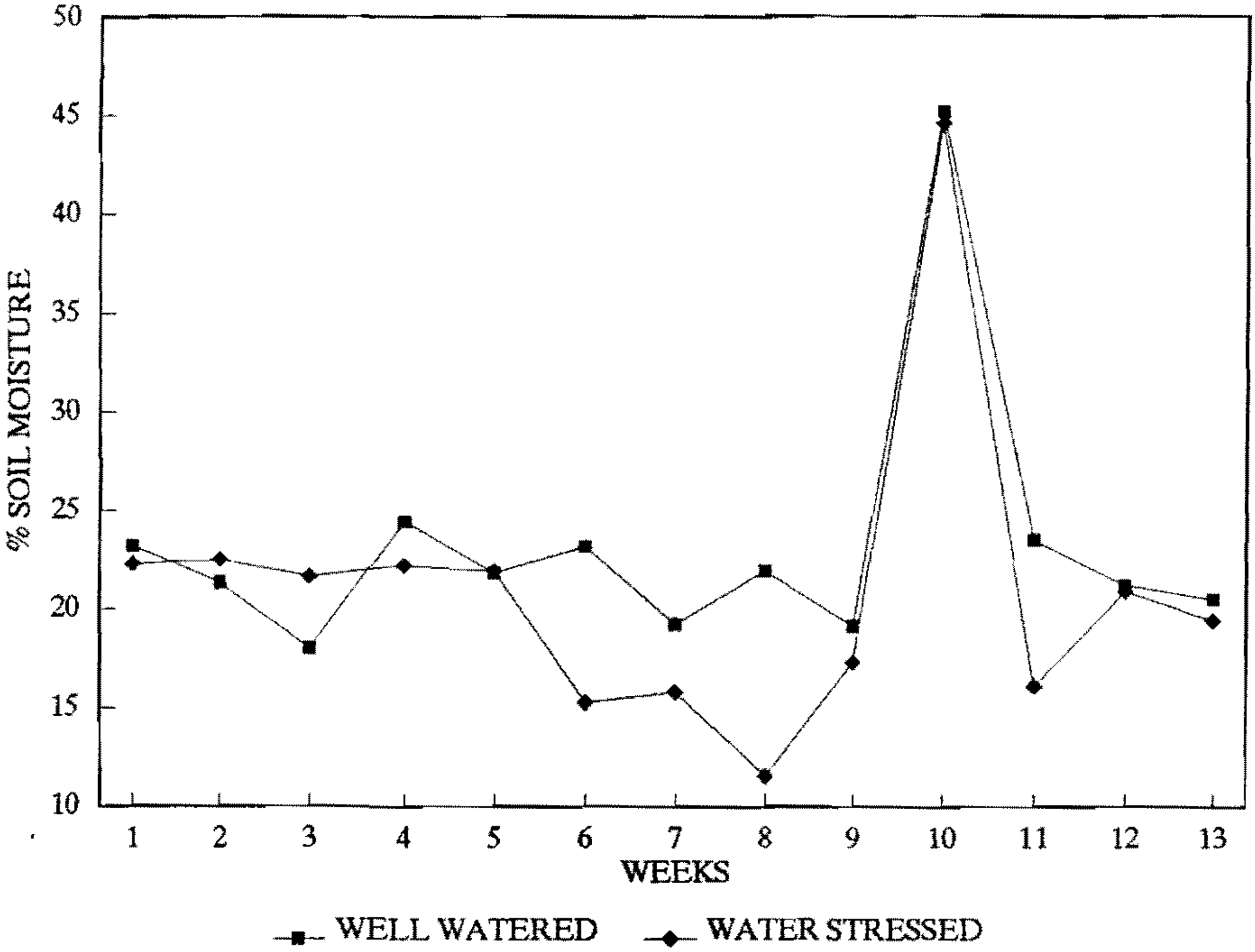
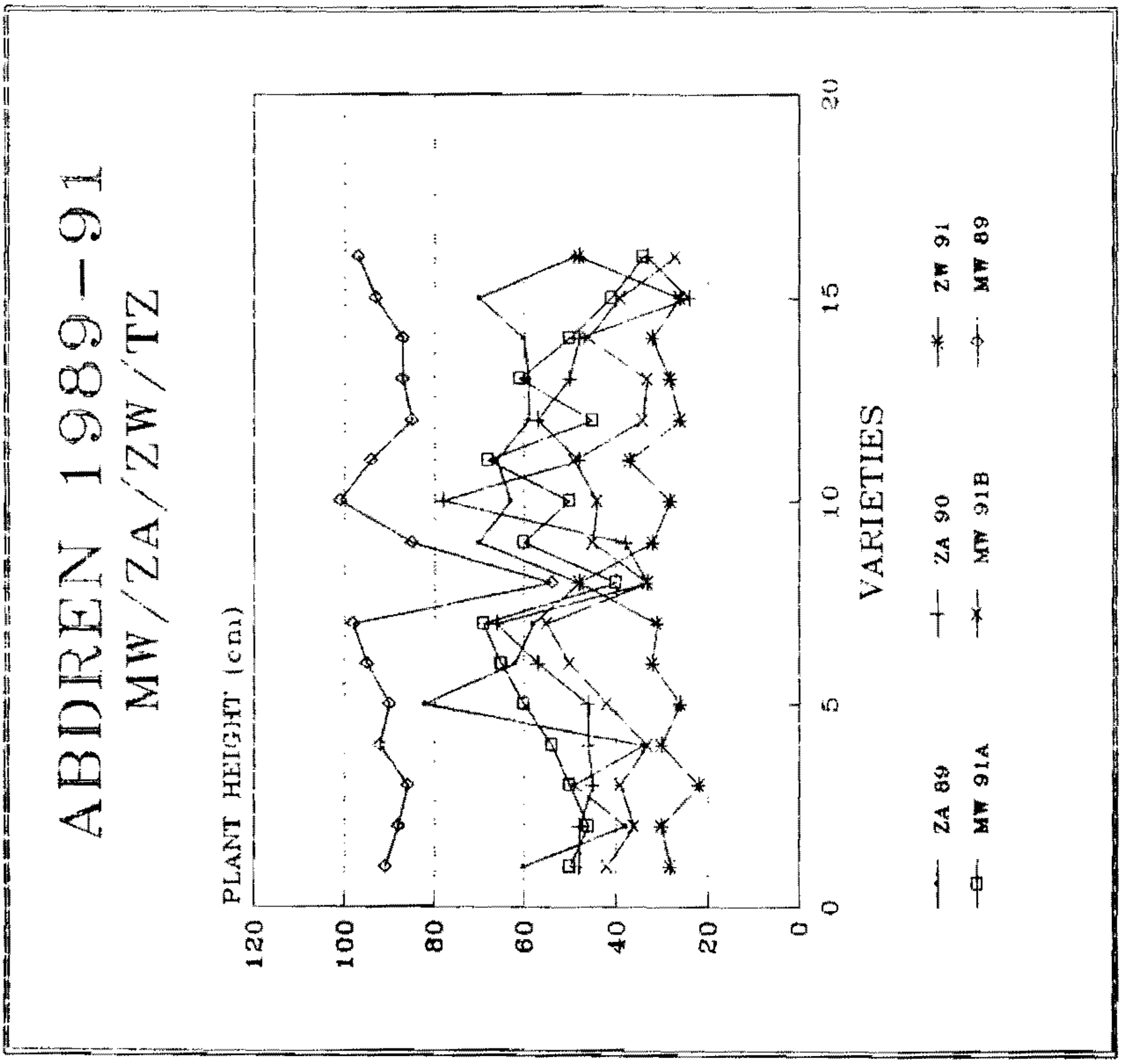


Figure 2.



ABDREN 1989-91
MW/ZA/ZW/TZ
PLANT HEIGHT (cm)
120
100
80
60
40
20
0
0
5
10
15
20
VARIETIES
ZA 89
ZA 90
ZW 91
MW 91A
MW 91B
MW 89

Figure 3.

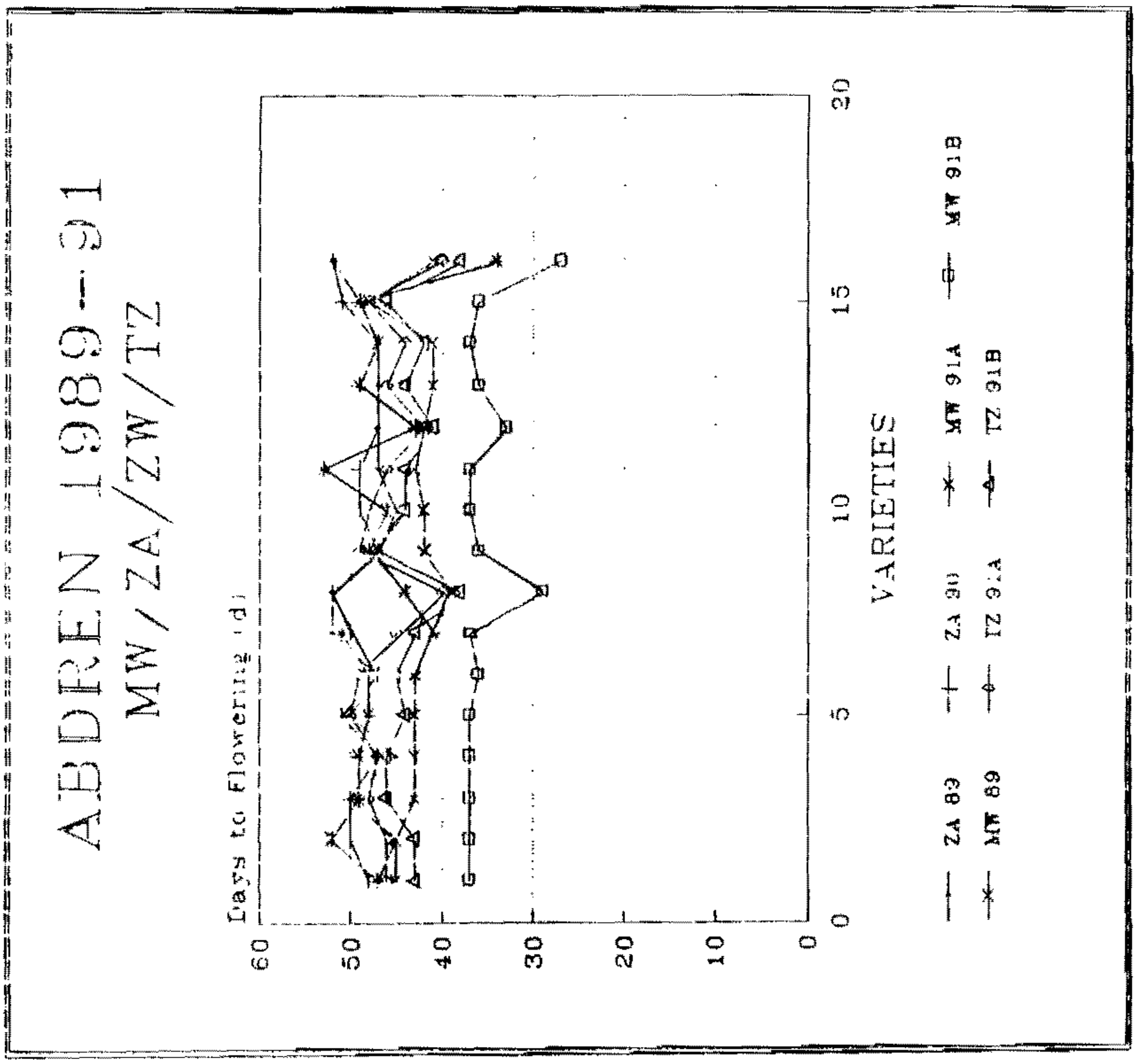
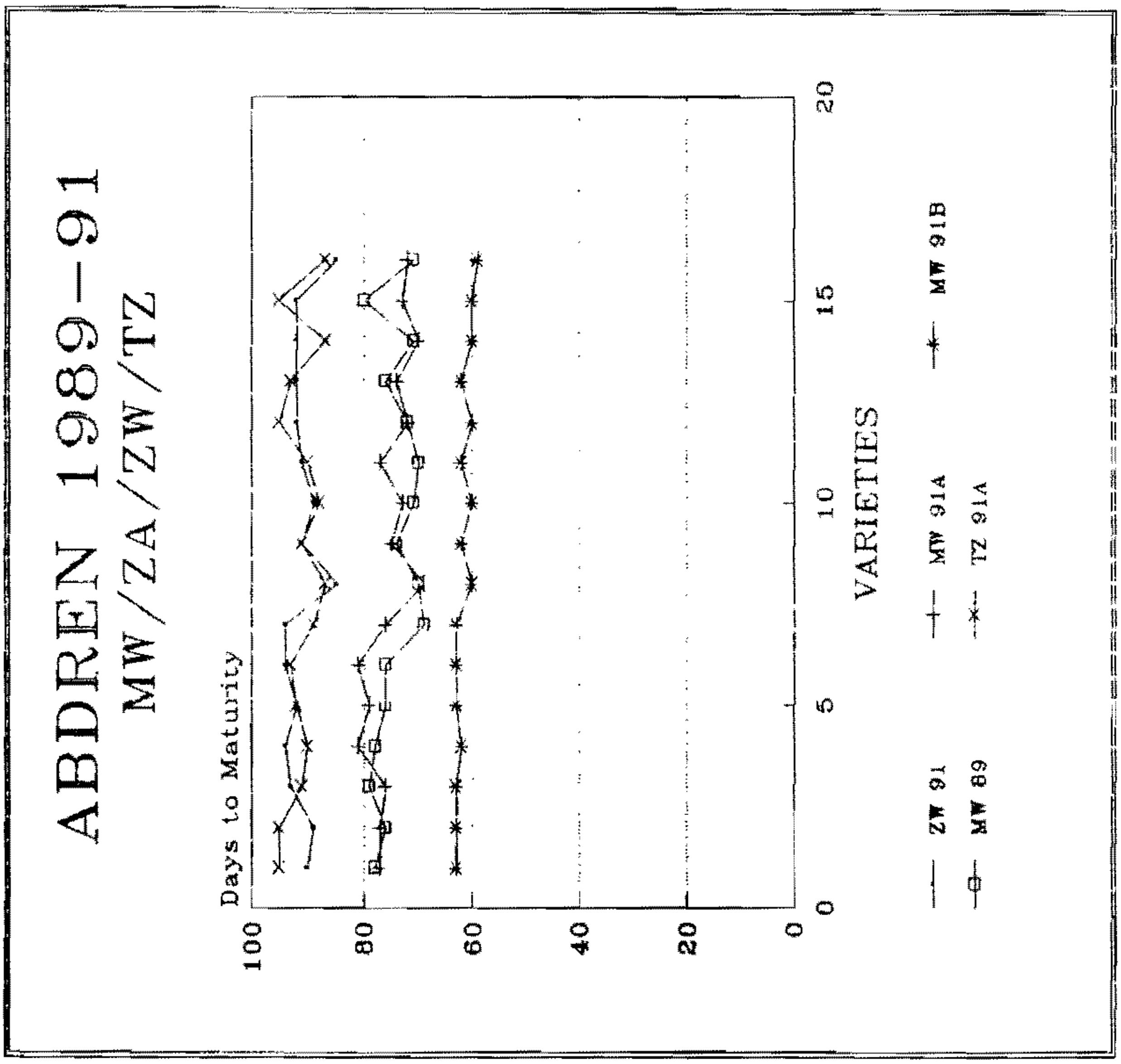
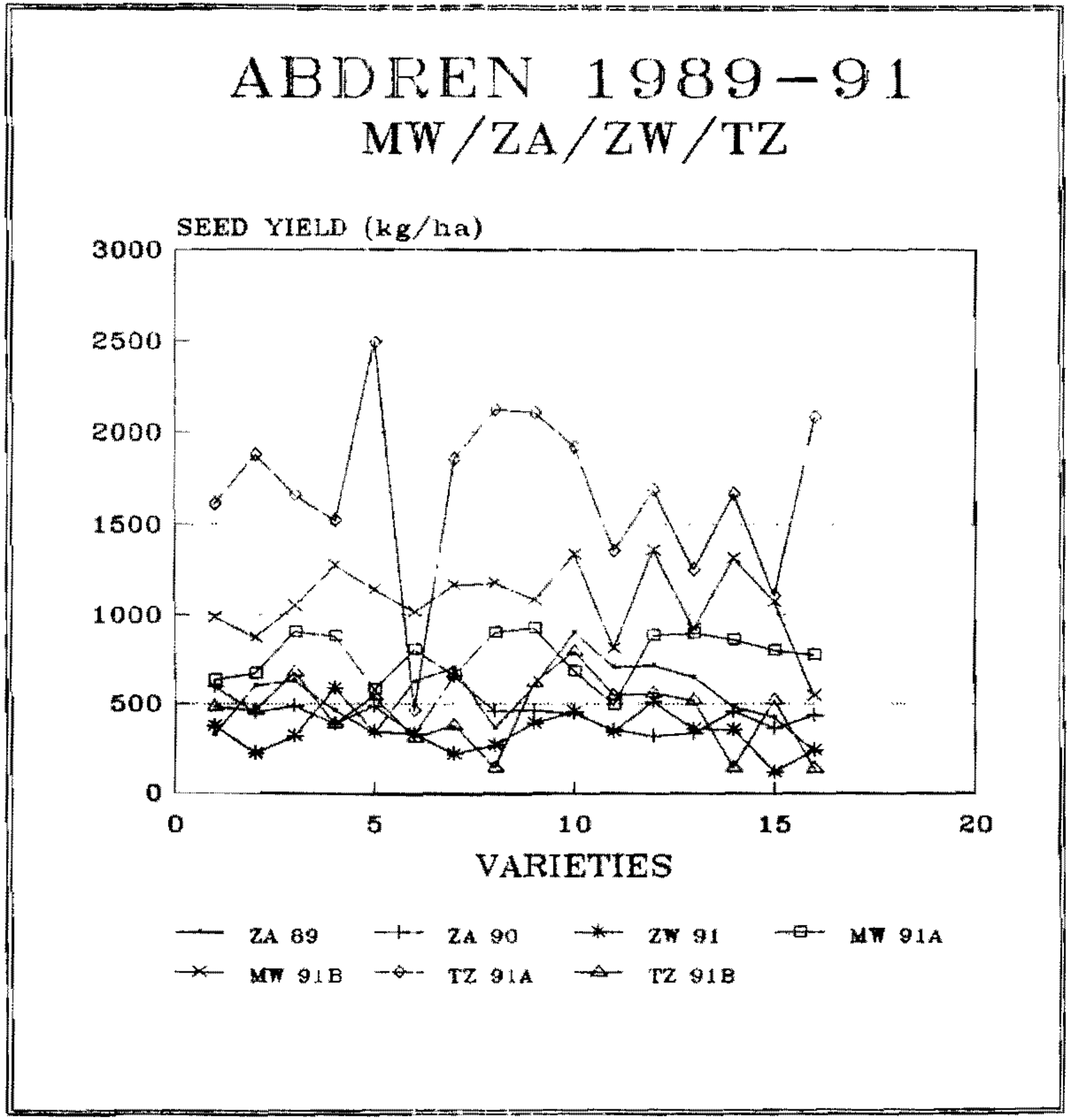

ABDREN 1989-91
MW/ZA/ZW/TZ
Days to Flowering (d)
VARIETIES
ZA 89
MW 89
ZA 90
TZ 91A
MW 91A
TZ 91B
MW 91B

Figure 4.


ABDREN 1989-91
MW/ZA/ZW/TZ
Days to Maturity
100
80
60
40
20
0
0
5
10
15
20
VARIETIES
ZW 91
MW 91A
MW 91B
MW 89
TZ 91A



ABDREN 1989-91
MW/ZA/ZW/TZ
SEED YIELD (kg/ha)
0
500
1000
1500
2000
2500
3000
0
5
10
15
20
VARIETIES
ZA 89
ZA 90
ZW 91
MW 91A
MW 91B
TZ 91A
TZ 91B

Figure 5.

IMPROVED SOIL FERTILITY INCREASES NODULATION OF Phaseolus BEANS

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ABSTRACT

The effect of soil fertility on the response of field beans (Phaseolus vulgaris L.) to inoculation with Rhizobium leguminosarum bv. phaseoli was investigated at five sites in northern and central Malawi. A split -plot design consisting of (a) un-inoculated plants, (b) inoculated plants and (c) N-fertilized plants as main-plot treatments and (i) low fertility (no additional nutrients applied) and (ii) high fertility (P, S, and Mo applied) was adopted. Nodulation was highest at Sokola (84 nodules per plant) and lowest on an acid soil at Lunyangwa (11 nodules per plant). There was no significant response ($p > 0.05$) in nodule number to inoculation at all sites, i.e., un -inoculated plants formed as many nodules as inoculated plants. This is indicative of a large population of indigenous rhizobia in the soils, which implies that competition for nodulation between inoculant and indigenous rhizobia is probably an important factor in response to inoculation. Improved soil fertility increased nodule number by up to 500 percent,probably by stimulating multiplication of rhizobia in the bean root rhizosphere. However, improved nodulation was translated into a significant increase in grain yield only at Champhira, where correlation between nodule number and grain yield was also significant ($r = 0.72$, $p < 0.01$).

INTRODUCTION

The response of a legume to inoculation with rhizobia depends on factors involving the bacterium, the plant and the environment in which the symbiosis is established. One of the most important environmental factors that will affect both *Rhizobium* and the plant is the fertility status of the soil. Phosphorus has been demonstrated to be one of the most limiting factors to nitrogen fixation in legumes grown in tropical soils in Africa (Keya, 1977), Latin America (Hernandez et al., 1982) and Australia (Andrew and Jones, 1978). Sulphur (Edwards, 1977) and molybdenum (de Yunda and de Gonzalez, 1982) are also known to be important nutrient elements in legume *Rhizobium* symbiosis. They are both components of nitrogenase, the N-fixing enzyme of rhizobia, although recent evidence points to the existence of nitrogenase without Mo (reviewed by Pau, 1991). The objective of the experiment described here was to assess the role of soil fertility, particularly P, S and Mo, in terms of the response of beans to inoculation in Malawi.

MATERIALS AND METHODS

The experiment was conducted at Sokola in the Misuku Hills (Chitipa district), Ng'onga (Rumphi district), Lunyangwa (Mzuzu in Mzimba district), Champhira (Mzimba district) and Dedza (Dedza district). Some of the soil properties of these sites are presented in Table 1. All the soils had low contents of organic matter, total N and available P; these were ideal conditions for this inoculation and fertilizer experiment. Only the soil at Lunyangwa had low pH with high exchangeable Al. At each site, the experiment consisted of two parts in three replicates. One part, which was aimed at evaluating response to inoculation and the overall effect of soil fertility, consisted of two factors arranged in a split-plot design:-

(A) Source of N as a main-plot factor:-

(a) I_0N_0 : Un-inoculated, without fertilizer N (i.e., N from soil).
(b) I_1N_0 : Inoculated, without fertilizer N (i.e., N from rhizobia).
(c) I_0N_1 : Un-inoculated, with fertilizer N at 100kg N ha^{-1} (i.e., N from fertilizer).

(B) Fertility level as a sub-plot factor:-

(i) F_0 : No other nutrients added to soil.
(ii) F_1 : P, S and Mo added to soil.

The other part of the experiment was designed to find out which of the three added nutrients was most important to inoculated plants. Thus, the inoculated treatment (I_1NO) had the following extra treatments in a randomized complete block design:

(i) : No other nutrients added to soil.
(ii) : P added.
(iii) : S added.
(iv) : Mo added.
(v) : P and S added.
(vi) : P and Mo added.
(vii) : S and Mo added.

(viii): P, S and Mo added.

Seeds of *Phaseolus vulgaris* L. genotype 25-2 (a Type 2 genotype), were sown 0.1m apart in single rows on ridges 0.9m apart (i.e, 111,111 plants ha^{-1}). In the treatments that required inoculation, the seeds were inoculated with peat-based inoculant of the recommended strain of *Rhizobium leguminosarum* bv. *Phaseoli* in Malawi, MG 336, prior to planting. Phosphorus at 40kg P_2O_5 ha^{-1}, as triple superphosphate, sulphur at 30kg S ha^{-1} as gypsum and molybdenum at 1kg Mo ha^{-1} as ammonium molybdate were applied in appropriate treatments at planting. One third of the 100kg N ha^{-1} was applied as urea at planting and two thirds 21 days after planting. The plots were regularly weeded.

Nodules were counted on eight plants per treatment at 50 per cent flowering, typically seven weeks after planting. At physiological maturity, grain yield at 12.5 per cent moisture content was determined at Ng'onga, Lunyangwa and Champhira. The N content of the grain was analysed by the Kjeldahl method and the N percentage in grain multiplied by grain yield per hectare to get grain N yield per hectare.

RESULTS AND DISCUSSION

Nodulation

General

Nodulation was highest at Sokola (mean 84 nodules $plant^{-1}$) and lowest at Lunyangwa (mean 11 nodules $plant^{-1}$) (Table 2). One of the reasons for the high nodulation at Sokola may be the high moisture content in the soil at the time of planting. However, soil acidity (high exchangeable Al, Table 1) was probably a major factor in poor nodulation at Lunyangwa. A lime treatment is recommended in future experiments at Lunyangwa.

Response to inoculation

At all the sites, un-inoculated (I_0N_0) plants nodulated as much as inoculated (I_1N_0) plants, i.e., there was no significant response ($P < 0.05$) in nodule number to inoculation (Table 2). Lupwayi et al. (1991) reported similar results for other sites in Malawi. This is a reflection of a large population of indigenous rhizobia capable of nodulating beans at these sites. In such situations, competition for nodule formation between inoculant strains and indigenous strains is a very important factor in the response of a legume to inoculation. Analysis of nodule occupancy is required to find out the proportion of nodules formed by the inoculant strain in inoculated plants. Therefore, criteria for *Rhizobium* strain selection must include nodulation competitiveness. N fertilizer did not significantly suppress nodulation, probably because it was split-applied.

Lack of response to inoculation due to a large population of established indigenous rhizobia is generally true in all places where a particular legume has been grown traditionally for a long time. Other examples include *Phaseolus* beans in Latin America (Graham, 1981), soya beans in the Midwest of United States of America (Moawad et al., 1984), subterranean clover in Australia (Roughley et al., 1976) and white clover in United Kingdom (Newbould et al., 1982) and New Zealand (Rys and Bonish, 1984).

Response to improved soil fertility

Improving the fertility of the soil by adding P, S and Mo markedly increased ($P < 0.05$) the number of nodules formed by the plants (F_0 vs F_1) in both inoculated and uninoculated treatments at all sites except Dedza (Table 2). Interaction between soil fertility and the main-plot treatments was not significant, soil fertility improved nodulation in un-inoculated, inoculated and N-fertilized plants (Figs. 1a, 2a, 3a and 4a). It is likely that the improved fertility stimulated rhizobia multiplication in the soil either directly or through improved plant growth, which increased production of root exudates in the rhizosphere.

At Dedza, on the other hand, improved fertility surprisingly reduced nodule number (Table 2), particularly in inoculated treatments (Fig. 5a). The reason for such a different response at this site is unknown, especially as the soil properties were not much different from the other sites (Table 1). It is possible that improved soil fertility also stimulated multiplication of other soil microorganisms antagonistic to rhizobia.

Addition of individual nutrients to inoculated plants resulted in significantly different ($p < 0.05$) nodulation at Ng'onga (Fig. 1b), Champhira (Fig. 3b) and Sokola (Fig. 4b). At Ng'onga and Sokola, addition of P and/or S generally increased nodulation over the no-fertilizer control, whereas addition of Mo did not affect nodulation. For Mo, which is a nutrient required more for nodule function than for plant growth, a decrease (or non-significant increase) in nodule number and weight on its addition to soil indicates that it is deficient in the soil (Robson, 1978). Deficiencies of such nutrients lead to N deficiency in plants, which results in compensatory increase in nodule development, hence the higher nodule number and weight in deficient soils. By contrast, addition of other nutrients like P and S increase nodule number and weight in deficient soils. Therefore, the soils at these two sites might be deficient in P, S and Mo. However, this is not reflected in grain yields, which were not significantly different on addition of different nutrients at these sites (see below and Figs 1d and 3d).

At Champhira, P and/or S increased nodulation more when Mo was also added than when it was not, although it was only the addition of all the three nutrients that resulted in a significant increase over the control (Fig. 3b). Although not significantly, grain yield results followed a similar trend (Fig. 3d), which is suggestive of Mo deficiency.

Grain Yield

Of the three sites where grain yields were determined, Ng'onga had the highest mean yield (653 kg ha^{-1}) and Lunyangwa the lowest (120 kg ha^{-1}). Apart from the effects of soil acidity, the yields at Lunyangwa were low because of heavy damage of the plants by bean-fly.

A response to inoculation, N fertilizer and improved soil fertility was obtained only at Champhira, where 39, 102 and 35 per cent increases over the respective controls were realized (Table 3 and Fig. 3c). Addition of different nutrients to inoculated plants had no significant effect on grain yield at any site (Figs. 1d, 2d and 3d).

Correlation between nodule number and grain yield

For each site, correlation between the number of nodules per plant and grain yield was calculated for all treatments except those that had been fertilized with N. The N-fertilized treatments were excluded from these calculations because application of N suppressed nodulation (although not significantly) but increased grain yield.

There was no significant correlation between nodule number and grain yield at Ng'onga ($r = 0.27$ NS) or at Lunyangwa ($r = 0.30$ NS), but a highly significant correlation was obtained at Champhira ($r = 0.72$ **). This is the same site where there was a significant response of grain yield to inoculation, N fertilizer and improved soil fertility (Table 3 and Fig. 3c).

General remark

All the yields were lower than expected because of drought during the season. The response of plants to inoculation and fertilizer application is heavily dependent on availability of adequate soil moisture for the rhizobia to multiply and the fertilizer to dissolve. Because the potential yields of the plants with N fertilizer were not realized, assessment of the relative nitrogen fixation potential of the indigenous rhizobia was difficult. Therefore, the experiment is being continued in order that seasonal variations in climatic conditions are taken into account. However, it should be pointed out that the plant population (of 111,111 plants per hectare) that was used is half the recommended density for dwarf beans. Most farmers in Malawi prefer to plant one row, instead of the recommended two, on the standard 0.9m ridges.

CONCLUSION

This work has shown that nodulation response of beans to inoculation was limited by the presence of a high population of indigenous bean rhizobia in the soil, as indicated by the high nodulation in uninoculated plants, and low soil fertility. However, the response in grain yield to improved soil fertility was inconsistent, probably because response to fertilizer was masked by drought during the season.

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Table 1. Some top soil (0-15cm depth) characteristics of the experimental sites used in Malawi.

Site	**Texture**	**pH %**	**Org.C**	**%N Avail P (ug g-1)**	**Bray**	**Exch. H**	**Exch. Al**
						(meq./100g soil)	
Sokola	C	6.2	1.53	0.11	0.72	0.40	1.60
N'gonga	SCL	6.7	1.49	0.12	1.72	0.60	1.40
Lunyangwa	SC	5.0	1.05	0.10	1.28	0.20	6.60
Champhira	C	6.0	0.83	0.07	1.92	0.80	1.40
Dedza	C	5.6	1.35	0.10	2.93	0.40	1.60

Table 2. Effects of inoculation, N-fertilization and soil fertility on nodule number.

Treatment	Nodules/plant				
	Sokola	Ng'onga	Lunyangwa	Champhira	Dedza
I_oN_o[a]	100a[b]	52a	13a	22a	39a
I_1N_o	96a (-4%)[c]	37a (-29%)	13a (0%)	45a (105%)	52a (33%)
I_oN_1	55a (-45%)	15a (-71%)	6a(-54%)	30a (-36%)	23a (-41%)
s.e.	17	14	4	7	8
F_o	31b	29b	3b	10b	42a
F_1	136a (339%)	41a (41%)	18a (500%)	55a (450%)	34b (-19%)
s.e.	8	3	2	5	2

[a]I_oN_o = Un-inoculated, without N fertilizer.
I_1N_o = Inoculated, without N fertilizer.
I_oN_1 = Un-inoculated, with N fertilizer.

F_o = Low soil fertility (no nutrients added).
F_1 = High soil fertility (P, S and Mo added).

[b] Vertical means (for each factor) followed by the same letter are not significantly different at 5% significance level.

[c] Per cent increase or (-) decrease compared to the control for each factor.

Table 3. Effects of inoculation, N-fertilization and soil fertility on grain yield.

Treatment	Grain yield (kg ha^{-1})		
	Ng'onga	Lunyangwa	Champhira
I_0N_0[a]	716a	112a	359c
I_1N_0	536a (-25%)	138a (23%)	500b (39%)
I_0N_1	708a (-71%)	110a (-2%)	724a (102%)
s.e.	113	16	17
F_0	703a	105a	448b
F_1	603a (-14%)	135a (29%)	607a (35%)
s.e.	103	9	19

[a] I_0N_0 = Un-inoculated, without N fertilizer.
I_1N_0 = Inoculated, without N fertilizer.
I_0N_1 = Un-inoculated, with N fertilizer.
F_0 = Low soil fertility (no nutrients added).
F_1 = High soil fertility (P, S and Mo added).

[b] Vertical means (for each factor) followed by the same letter are not significantly different at 5% significance level.

[c] Per cent increase or (-) decrease compared to the control for each factor.

Fig. 1a. Effect of inoculation and soil fertility on nodulation at Ng'onga.

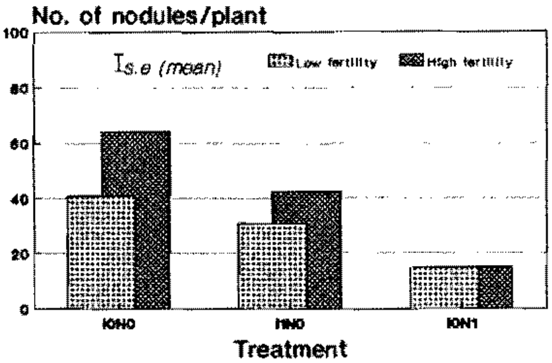


Fig. 1b. Effect of added nutrients on nodulation at Ng'onga.

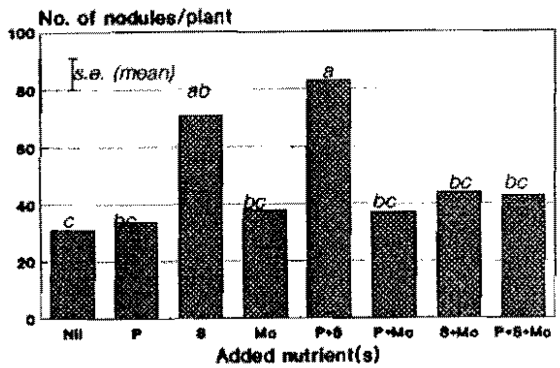


Fig. 1c. Effect of inoculation and soil fertility on grain yield at Ng'onga.

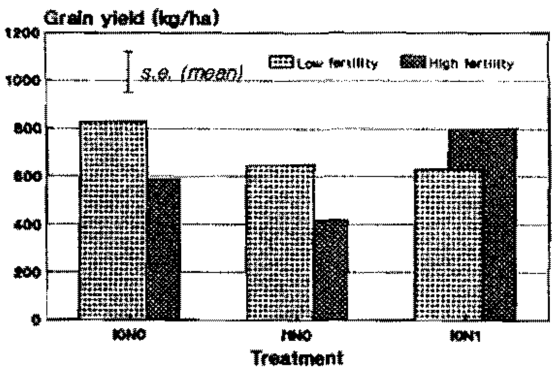


Fig. 1d. Effect of added nutrients on grain yield at Ng'onga.

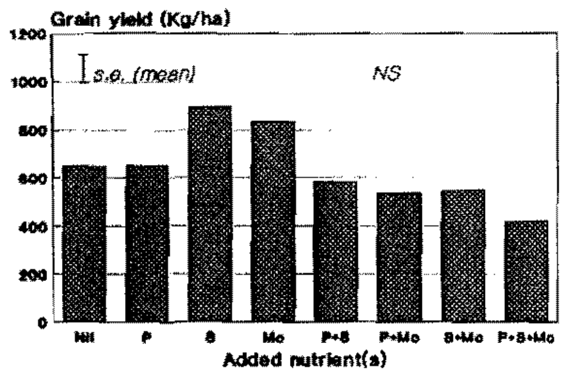


Fig. 2a. Effect of inoculation and soil fertility on nodulation at Lunyangwa.

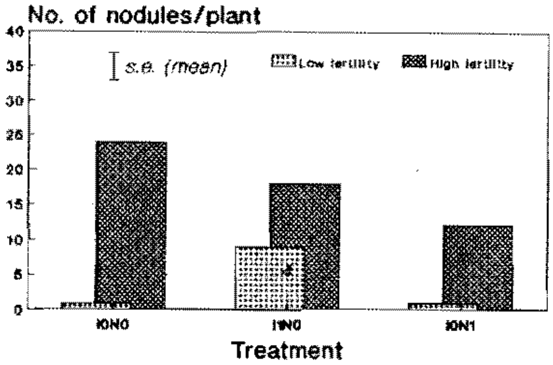


Fig. 2b. Effect of added nutrients on nodulation at Lunyangwa.

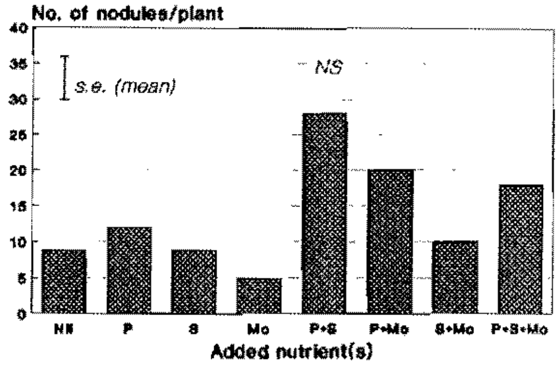


Fig. 2c. Effect of inoculation and soil fertility on grain yield at Lunyangwa.

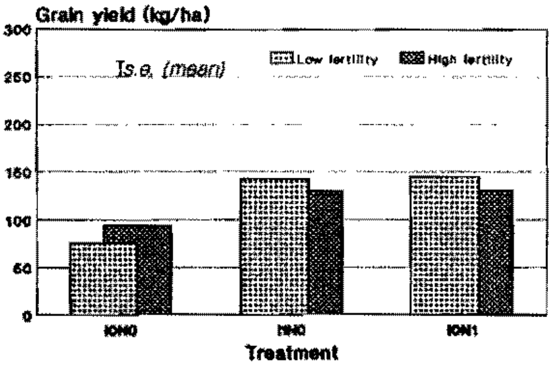


Fig. 2d. Effect of added nutrients on grain yield at Lunyangwa.

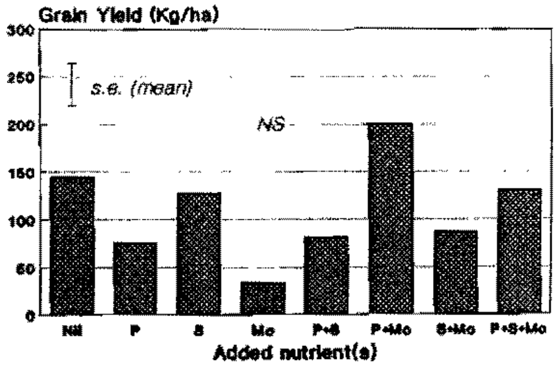


Fig. 3a. Effect of inoculation and soil fertility on nodulation at Champhira.

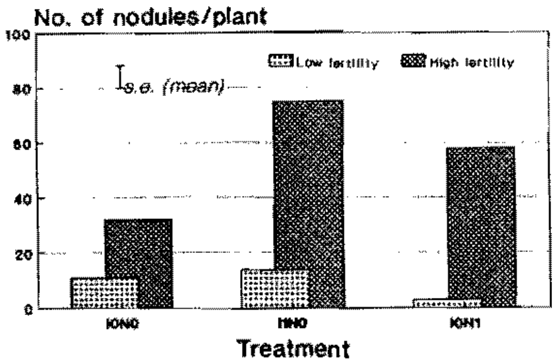


Fig. 3b. Effect of added nutrients on nodulation at Champhira.

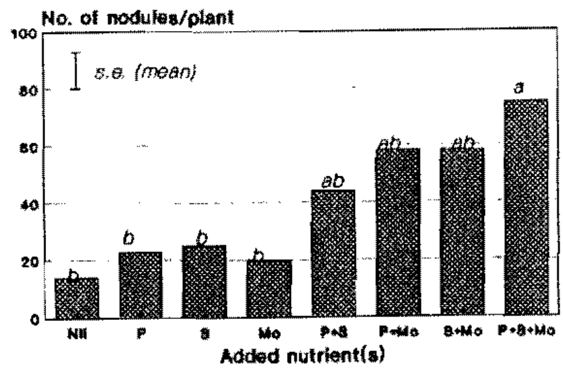


Fig. 3c. Effect of inoculation and soil fertility on grain yield at Champhira.

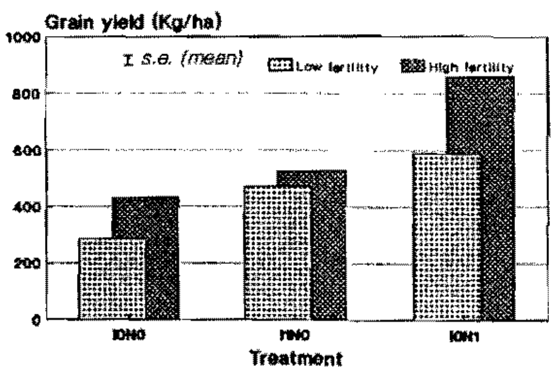


Fig. 3d. Effect of added nutrients on grain yield at Champhira.

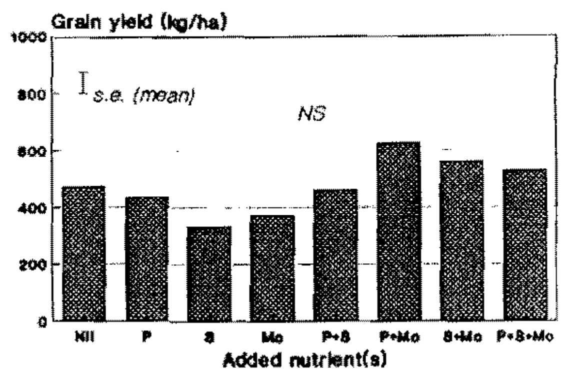


Fig. 4a. Effect of inoculation and soil fertility on nodulation at Sokola.

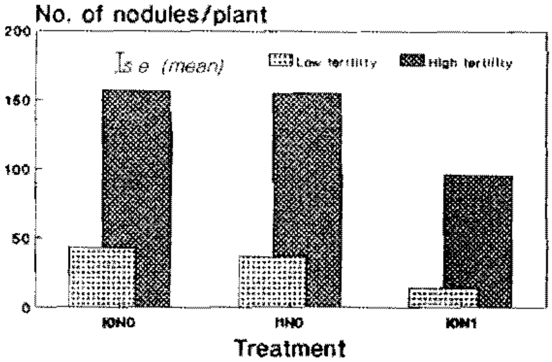


Fig. 4b. Effect of added nutrients on nodulation at Sokola

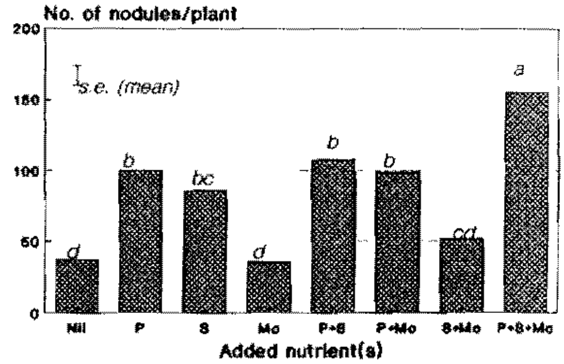


Fig. 5a. Effect of inoculation and soil fertility on nodulation at Dedza.

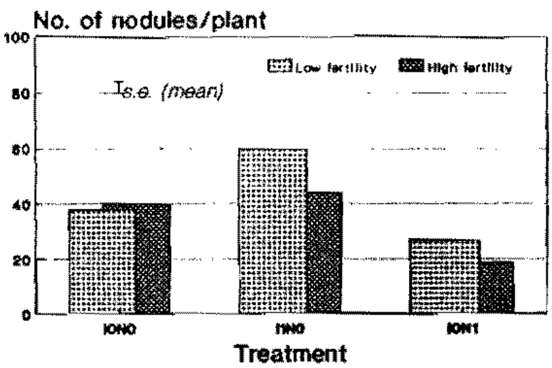
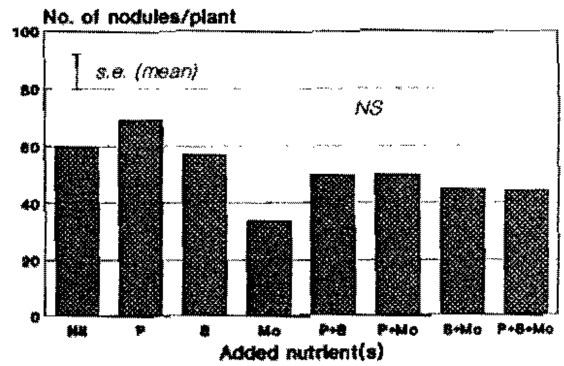


Fig. 5b. Effect of added nutrients on nodulation at Dedza.



EXPERIENCES WITH TWO PROMISING MULTIPLE CROP SYSTEMS WITH COMMON BEANS IN MOZAMBIQUE

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ABSTRACT

1. Bean x Maize

Twelve bean varieties are being tested for direct association with maize. Main results indicate that none of the bean varieties reduced the dry grain yield of maize variety Matuba, which was 2500 kg/ha. Bean varieties Manteiga and Kazama, with an average yield of 470 kg/ha, significantly out-performed ten other varieties. Under local conditions, this yield level would be acceptable, and would be a bonus to small farm growers of monocrop maize to whom this technology is being proposed.

2. Cowpeas x Rice x Beans sequential pattern

The study of the sequential crop pattern cowpea/rice/beans has been started with the objective of investigating more efficient uses of land and available resources, in highly specialized rice growing areas of Mozambique. For these areas, available resources are irrigation, hand labour and seasonal temperature changes. First results indicate rice benefitted by previous cowpea planting and that planting beans after rice is feasible. Average yields were 2,900 kg/ha of rice as a monocrop treatment, 775 kg/ha of cowpea grain and 3,400 kg/ha of rice, and 500 kg/ha of dry grain beans in a sequential crop of cowpeas/rice/beans.

INTRODUCTION

As in other common bean growing countries, there are several potential growing patterns that could be introduced to Mozambique and implemented as a means of increasing food production and using both soil and labor. Because there are different growing areas with well-defined climatic environments and basic crops in Mozambique, two crops have been chosen as initial models : these are maize and rice.

Maize is the most common crop of the region, and there are many areas where it is grown as a monocrop. Some of those areas have a good potential for introducing several intercrop patterns with beans. There are also a few highly specialized rice-growing areas which may be suited for additional production of beans. The approach to multiple crop methodologies for these two crops has been to keep their local technologies unmodified. Direct association of maize/beans, and sequential schemes of cowpeas/rice/beans are being examined. Some preliminary results are reported in this paper.

MATERIALS AND METHODS

Evaluation of bean varieties for association with maize

Twelve varieties of beans (Table 1) were planted in direct association with the local maize variety, Matuba. Five seeds of maize and three of beans were sown simultaneously in the same hill. Thinning at 3x2 maize-beans plants was done three weeks after germination. Maize was planted in plots of two rows, 1m apart and 7m long, at a spacing of 0.8m. Experimental design used was randomized complete block with 3 replications; supplementary irrigation was applied. The experiment was planted on 18 April, 1991 at Umbeluzi Experimental Station; beans were harvested on 12 August and maize on 24 September.

Beans as a component in a sequential pattern with cowpeas for rice areas

Sequential treatments studied were:

1. Rice
2. Cowpeas - Rice
3. Cowpeas - Rice - Beans
4. Rice - Beans

Each treatment had four replications. Cowpeas and beans were either planted before or after rice in the same plot, according to the treatment. Plot size was 6x5 m. Regular irrigation was applied as necessary. The rice variety IR 52, cowpea INIA 36 and 'Manteiga' beans were used. Cowpeas were sown on 23 October, 1991; rice was transplanted on 27 February, 1992; and beans were sown on 4 July, 1992.

RESULTS AND DISCUSSION

Evaluation of bean varieties for association with maize

Data presented in Table 1 indicate that none of the bean varieties affected maize yield when planted in direct association. There were significant differences between yields of bean varieties when associated with Matuba maize. Although bean yields were not high, these experimental data look encouraging : under local conditions, dry grain yields of 400 kg/ha are regarded as good. Furthermore, such production only requires bean seed and harvesting above those costs incurred in sole crop maize production.

Beans as a component in a sequential pattern with cowpeas for rice areas

Average grain yields obtained for each crop are presented in Table 2. Plantings were a little late. Bean plots were rather lacking (grade 3) in vigor, perhaps either caused by an effect of the previous sequential crop or by late planting. This first experiment shows that it is possible to grow beans after irrigated rice under experimental conditions, suggesting it may be possible to extend the system to small farm rice growers in Mozambique.

It looks as if cowpeas provide some positive residual effect upon rice, and the triple sequential crop cowpea/rice/beans data would indicate a more efficient land utilization. For Mozambique, the hot weather of the second semester of the year is ideal for cowpeas and rice; then, after the normal rice harvesting season, the cooler season is ideal for the bean crop.

Table 1. Dry grain yields (in kg/ha), number of plants harvested and bean rust severity obtained in an evaluation of twelve varieties of beans in association with maize, variety Matuba, Umbeluzi.

Varietal Associations	Yields (kg/ha)		No plants harvested		Bean rust sever.
	Beans	Maize	Bean	Maize	
MATUBA (alone)	---	2.750a	---	158	---
MANTEIGA-SEL X MATUBA	479a	2.604a	107	124	2
KAZAMA X MATUBA	429ab	2.300a	89	138	1
ENCARNADO X MATUBA	375ab	2.446a	87	139	2
TROPA X MATUBA	312ab	2.458a	82	143	2
COS-4 X MATUBA	312ab	2.561a	83	152	1
KANTESA X MATUBA	292ab	2.008a	72	145	2
INIA-7 X MATUBA	283 bc	2.292a	87	125	2
MANTEIGA X MATUBA	229 bc	3.187a	64	145	3
DIACOL CALIMA X MATUBA	208 c	2.758a	63	156	2
KACHINA X MATUBA	208 c	2.508a	57	130	2
NOGOLO X MATUBA	187 c	2.508a	64	148	4
ENCARNADO RAIADO X MATUBA	125 d	3.000a	42	153	4
C.V.%	19.95	23.22			

Means followed by the same letter are not significantly different, at 5% level of probability.

Table 2. Grain yields (kg/ha) obtained in a cowpea/rice/beans sequential cropping pattern, Umbeluzi, 1991-92.

	Grain yields (kg/ha)		
Sequential treatment	Cowpeas	Rice	Beans
Rice (alone)	---	2,947	---
Cowpeas/Rice	744	3,322	---
Cowpeas/Rice/Beans	755	3,555	487
Rice/Beans	---	3,405	554

BEAN RESEARCH IN NAMIBIA 1991/92

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ABSTRACT

Bean research in Namibia is still at an early stage and the crop is not high priority at the moment. We are looking for a variety which will be adapted to Namibia's extremely harsh conditions. A report of IBYAN 1991/92 is given.

DISCUSSION OF THE AGRONOMY SESSION'S PAPERS

Aggarwal : How many varieties did Lupwayi use in his trial ?

Lupwayi : One variety : 25-2

Aggarwal : What are the possible reasons for the poor performance of the trial in some locations ?

Lupwayi : This (1992) has been a difficult year. We had 7 sites to start with but at Bunda and Thyolo there was a total crop failure. Misuku hills had a better rainfall. Fertilizer trials require good moisture for the fertilizer to be dissolved and absorbed by the plant.

Aggarwal : Late sowing may have contributed to the poor crop growth.

Lupwayi : Yes, perhaps. Bean stem maggot and soil acidity also contributed.

Bosch : At what stage were nodules counted, and were the data on nodule counts transformed before analysis ?

Lupwayi : Sampling for nodules was conducted around mid- flowering, at about 50 days after emergence. The data were not transformed because a plot on a scatter diagram followed a near- normal distribution.

Edje : This trial is very important especially on-farm, as it is a kind of exploratory trial. There is need to better control management to produce more reliable results.

Youngquist : Do we expect better nodulation and N2 fixation in intercrop conditions, with reference to Arias' paper ? We know increased N2 levels reduce nodulation and maize may reduce N2 levels.

Arias : Beans were not nodulating in Mozambique. A wide range of varieties have been tested and we do not understand why.

Edje : Ofori and Stern, working in Western Australia, reported that shading and competition lead to poor nodulation. I am surprised that Dr. Arias thinks intercropping is a new technology.

Arias : Not enough studies have been done in this area in Mozambique, and to me this area is a novelty.

Edje : Umbeluzi is not an ideal site for bean/maize intercropping.

The location is too hot, perhaps more suitable for cowpea.

Arias : The cool dry summers are suitable for beans in intercrops.

Allen : Various intercropping workshops have been held in the region : In Morogoro in 1976 and 1980; and in Lilongwe in 1989; and a lot of intercropping work has been done in Zambia. We need to build on the existing knowledge. The subject has not been particularly well addressed but it is not true to say "there is no information".

Teri : I am impressed by the idea of a network approach, as described by Mkandawire. Has anybody within the network looked at the genetic mechanisms of drought tolerance ?

Mkandawire : No, not yet. We need to identify characteristics that lead to drought tolerance before we embark on genetic studies. Plants with drought tolerance are generally those that retain vigour in the face of moisture stress. Possible characteristics may include leaf area. Root volume may also contribute, since they can scavenge better for moisture in the soil. Inheritance of bigger root systems is a possibility.

Youngquist : This will be a qualitative measure. Different genes may be responsible for different phases in the plant reaction to a drought situation. Jeff White has good information on root system response. He controls the drought situation but this is atypical. Drought tolerance is a quantitative trait.

Mkandawire : It is difficult to determine the physiological mechanism of drought tolerance. We know roots are playing a role but it is difficult to pinpoint the specific actions. Gene mapping may help and there is work being done by Paul Gepts in California and Shree Singh at CIAT on this. We hope to test their materials in Malawi.

Aggarwal : Were all your seeds small ?

Mkandawire : No, AND 197 is large seeded. G 5201 and BAT 798 are good genotypes. There are also G x E interactions.

SESSION 4 : CROP PROTECTION

THE BIOLOGY, ECOLOGY AND ECONOMIC IMPACT OF *Clavigralla* spp. IN LESOTHO

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ABSTRACT

Spiny brown bug (Clavigralla spp.) is known as a serious pest of legumes worldwide. Common beans (Phaseolus vulgaris L.) are most sensitive to spiny brown bug infestations. Farmers in Lesotho are currently increasing their bean acreages, consequently new pests are being encountered. This study investigated the occurrence, biology, and economic thresholds of spiny brown bug in common beans in Lesotho. Spiny brown bug is widespread throughout Lesotho although its populations are not yet serious, partly because beans are planted late in the season. However, patterns of adaptation to those late times are evident. The life cycle from egg to adult ranges from 17 to 36 days.There are five nymphal instars. Bean yields are seriously reduced by infestation. Bean yields were 1700 kg/ha with no infestation but significantly declined to 26.8 kg/ha when infested with 27 spiny brown bugs per 0.375 m^2 cages.

INTRODUCTION

Common beans (*Phaseolus vulgaris* L.) are an important dryland crop in Lesotho. For the past ten years the area cultivated to beans ranged between 7,500-30,000 hectares (Massey et al., 1989). Among the principal factors affecting bean production in Lesotho are rainfall, soil infertility, diseases and insect pests. Among the serious insect pests affecting bean production in Lesotho is the spiny brown bug, *Clavigralla* spp.

Spiny brown bug (SBB) has been recorded as a serious pest of grain legumes throughout Africa (Jackai and Daoust, 1986). Clavigralla spp. have been recorded on cowpeas (*Vigna unguiculata* Walp.), pigeon peas (*Cajanus cajans* [L.] Druce), common beans, hyacinth bean (*Lablab purpureus* [L.] Sweet) and sweet potato (*Ipomoea batatas* Lam.), (Materu, 1971; Egwuatu and Taylor, 1977; Jackai, 1984). *Clavigralla tomentosicollis* Stal. is the most widespread species and occurs in Tanzania, Nigeria, South Africa, Ghana and Kenya (Materu, 1970; Jackai, 1984; Egwuatu and Taylor, 1977; Agyen-Sampong, 1978; Khamala, 1978; Hill, 1983). *Clavigralla horrida* and *C. hystricoides* are also important in Tanzania (Materu, 1971).

Clavigralla spp. have been observed on common beans at the Agricultural Research Station in Lesotho where common beans are planted every year for research purposes (E. Pomela, pers. comm. 1987). The extent of its distribution and species composition in the country are not known, and the extent of crop damage relative to Clavigralla populations has not been determined. Consequently, appropriate management procedures have not been undertaken. In most instances, Lesotho acquires its pest control technologies from neighboring South Africa. Frequently, such technologies fail to perform to optimum levels because location specific technologies are not known.

The major objectives of this study are to identify the *Clavigralla* species composition in Lesotho, to study the biological elements affecting *Clavigralla* occurrence in Lesotho, and to determine the economic thresholds as a guide to management decisions.

MATERIALS AND METHODS

Surveys. In order to determine the distribution of *Clavigralla* in Lesotho, sixteen fields were surveyed. Location, altitude, crops planted, crop stage, insect populations and cropping patterns of each field were recorded in order to determine the spread of Clavigralla in Lesotho (Table 1). Locations ranged from Maseru, at an altitude of 1420 masl to Machache, at 1890 masl. Field locations were from Butha Buthe in the North to Quthing in the South of the country. Most fields sampled were planted to beans, and a few to soybeans and lucerne. Each field was sampled using a M-shape sequential sampling method, each with ten samples. Visual counts of adult insects per plant were taken on each field. Then the average number of insects per plant was determined. Surveys were done during January and February, 1992. At the January sampling, most bean fields were in the vegetative stage while for February sampling beans were in the reproductive stage.

Developmental times. The experiment was done inside a mesh enclosure. The temperatures inside the enclosure ranged from 25-34°C. Individual plot sizes were a wire mesh cage of 0.75 x 0.4 x 0.4 m with a potted bean plant for oviposition and shelter. Ten adult insects collected from the field were placed inside the cage. The insects were supplied with fresh green beans every 2 to 3 days. The plants were then examined daily for presence of eggs. Eggs were collected by excising the part on which they were laid and placing them in a petri dish. The time it took from egg-laying to egg-hatching was then recorded, as was the time for each subsequent growth stage. The first instar nymphs to hatch were placed individually in petri dishes with fresh beans and damp cotton wool, so as to provide food and moisture.

Economic thresholds. A field experiment, of a randomized complete block design, with four replications was conducted. Four insect populations of 0, 3, 9, and 27 insects per cage were used. These populations were chosen to reflect a sigmoidal response of bean yields to insect infestations. Cages measuring 0.75 x 0.50 x 0.50 m were used. The plot size was therefore 0.375 m^2. At the beginning of flowering (R1 stage) insects were placed in cages. The beans were harvested when dry, threshed and yields recorded. Analysis of variance was then performed and correlation of insect population to yield was determined.

RESULTS AND DISCUSSION

The results presented in this paper are for the 1991/92 season only. The study will be continued during the 1992/93 season.

Surveys. During the January surveys, most fields except at the Agricultural Research Station where beans are grown early in the season, had no spiny brown bug. During the February surveys, the resurveyed fields had spiny brown bug (Table 1). Insect populations ranged from 0 to 8 insects per plant. Most farmers' bean fields are planted late in the season, consequently beans are at R1 stage in February. Therefore, there is a definite relationship between the frequency of bean production, pattern of farming, crop phenology and spiny brown bug infestation. Maseru Agricultural Research Station had the highest populations (8 insects/plant) whereas other locations had low to no insects. The spiny brown bug was always present during the reproductive stage of bean plants and there was no particular podding stage favored. In all cases except one (a field at Ha Makoae 1 in Quthing), spiny brown bugs were present on beans. In addition to Maseru Agricultural Research Station, beans are also grown every year in Hololo and Leshoele and this seems to influence the presence of the spiny brown bug.

Developmental times. The complete life cycle from egg to adult takes 17-36 days for insects fed on fresh and dry beans. The developmental stages are similar to the ones recorded by Egwuatu and Taylor (1977). In this experiment, spiny brown bug had five nymphal instars with developmental times ranging from 3 to 6 days. However, the fifth nymphal instar took 5 to 9 days. These developmental times were recorded under controlled environment. However, developmental times in the field where temperatures have a wide variation are not known.

Economic thresholds. In general, bean yields were lower than normal because of the serious drought that prevailed in southern Africa. In addition, there was sporadic rust infection in beans, probably further causing yield loss. Bean yields were 1700 kg/ha where there were no insects, slightly decreased to 1387 kg where there were low populations of insects, and significantly decreased to 26.8 kg/ha with high insect populations (Table 3). There is a negative correlation of insect population to yields.

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Table 1. Insect populations of the fields surveyed in February.

Location	Altitude masl	No. insects per 10 plants	Crop	Crop Stage
*Maseru	1420	8	Beans	R1
Mafeteng	1440	.1	Beans	R5
Machache	1890	0	Beans	R6
Leribe	1580	3	Beans	R8
Thabana Tsooana 1	1430	5	Beans	R7
Thabana Tsooana 2	1430	2	Beans	R8
Ha Sakoane ARS	1480	0	Beans	R8
Ha Sakoane 1	1430	.2	Beans	R7
Ha Sakoane 2	1430	.5	Beans	R6
Ha Sakoane 3	1430	0	Beans	R7
*Hololo	1600	5	Beans	R4
Makoae	1800	0	Beans	R5
Makoae 1	1800	4	Lucerne	R
Thuathe	1800	0	Beans	R4
*Leshoele	1540	3	Beans	R6
*Masianokeng	1400	0	Beans	R5

* Supplemental irrigation

R=Reproductive Stage

Table 2. Developmental times of the spiny brown bug under controlled environment.

Developmental Stage	Developmental Times (Days)
Egg	1-4
1st Nymphal instar	2-6
2nd Nymphal instar	3-6
3rd Nymphal instar	3-5
4th Nymphal instar	3-6
5th Nymphal instar	5-9
Adult	

Table 3. Bean yield in response to insect Populations in the field.

Insect Populations	Yield (kg/ha)
0	1700
3	1380
3	1387
27	26.8

BEAN BRUCHID RESEARCH: RESULTS OF A SADC/CIAT REGIONAL SUB-PROJECT

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ABSTRACT

This paper presents some of the research results of a regional sub-project on bean bruchids that is jointly funded by SADC/CIAT and The Rockefeller Foundation. The research programme includes the following studies : i) survey of bean production and post-harvest practices by small scale farmers in Zimbabwe; ii) survey of bean bruchid species composition and distribution in Africa; iii) evaluation of selected traditional grain protection methods in laboratory and simulated storage trials; iv) preliminary agronomic evaluation of bruchid resistant germplasm ('RAZ' lines); v) screening of RAZ lines for bruchid resistance; vi) bruchid species incidence and populations in the field; vii) infestations of stored pods with time in storage; viii) solar disinfestation of beans; ix) evaluation of a sorptive dust as a grain protectant; and x) competition interactions between Acanthoscelides obtectus and Zabrotes subfasciatus at different temperatures.

INTRODUCTION

At the 2nd SADCC/CIAT Regional Bean Research Workshop held in Morogoro, Tanzania from 17-22 September 1990 a collaborative research proposal between Zimbabwe and Tanzania was presented (Giga et al., 1990). Its overall aim was to obtain a detailed knowledge of small farmers' bean storage systems, losses in storage, bruchid species composition and distribution and control methods. In recognition of the role of food storage as a vital component in the drive towards self-sufficiency and the improvement of the nutritional status of the small farmer through appropriate conservation techniques, the SADC/CIAT programme supported a regional sub-project based at the University of Zimbabwe. The research programme commenced in March 1991 and significant progress has been made. A number of experiments have been completed and several are in progress, although not all the project's objectives have yet been achieved. Several experiments have been conducted and their results are presented in this paper. The following studies have been completed, or are in progress:
i) survey of bean production and postharvest practices; ii) survey of bean bruchid species composition and distribution in Africa; iii) evaluation of selected traditional grain protectants in laboratory and simulated storage trials; iv) screening 'RAZ' lines for bruchid resistance; v) bruchid species incidence and populations in the field; vi) agronomic evaluation of 'RAZ' lines; vii) infestations of pods and threshed grain

(artificial and natural) with time in storage; viii) solar disinfestation of infested beans; ix) evaluation of a sorptive dust as a grain protectant; and x) interactions between *Acanthoscelides obtectus* and *Zabrotes subfasciatus* at different temperatures.

SURVEY OF BEAN PRODUCTION AND POSTHARVEST PRACTICES

A questionaire survey was conducted in 14 districts in 4 Provinces (Mashonaland east, Mashonaland central, Mashonaland west and Masvingo) of Zimbabwe to obtain information on bean production and postharvest practices. Beans are mainly planted in October to March and harvested from February to May. No accurate information was obtained on specific varieties grown by the farmers but the most common are sugar beans, Michigan pea beans and Red Canadian Wonder. Beans are mainly intercropped with maize and rarely fertilized. The area under bean cultivation varied widely among the different communal households, but 0.4 ha seems to be the best mean area estimate. Most of the small farmers used seed saved from previous harvests for planting while a few bought seed from various sources.

Beanfly infestations were mentioned by some farmers to be a major problem in the early seedling stages, with Michigan pea beans being the most susceptible. In general, however, no form of disease or pest management is practiced by small farmers. Bean yields also varied widely with the cropping system (intercropping versus monocropping), variety and level of crop management. Overall, the mean yield was estimated to be 216 kg per household (approximately equivalent to 490 kg/ha). Beans are stored in the threshed form in various containers including jute bags (50 kg or 90 kg), 20-litre tins, pots (clay and metal), plastic bags, empty flour bags, paper bags and drums (only for beans still in pods). These containers are usually kept in the granary (in which maize is stored) or in the house. The amounts stored and sold vary depending on the yield, but on avearage 20-30% of the total yield is stored for home consumption. Nearly 80% of all the farmers interviewed store beans for at least six months.

Bruchid damage was perceived by farmers as a major problem but no meaningful estimates of losses were obtained. Few farmers take measures to reduce bruchid infestation even though they realise the damage potential of these insects. The most common bruchid control measures include the use of insecticides, admixing beans with ash, rapoko (finger millet) husks and sand, and sunning. Smoking or alternating layers of leaves of eucalyptus, *Tagetes minuta* and tobacco are some methods used by a few other farmers. According to farmers, the effectiveness of all these simple control treatments range from poor (rapoko husks) to very effective (ash). The farmers feel that high storage losses coupled with an uncertain market have a negative impact on bean production.

DISTRIBUTION OF BRUCHIDS IN AFRICA

In order to obtain information on the distribution of *Z. subfasciatus* and *A. obtectus* in Africa, a 'postal survey' was conducted. Over 70 questionnaires requesting information on the species attacking beans in storage and details of climate, altitude and temperature where the species are known to occur were sent to entomologists, bean researchers and directors of agricultural research institutes in southern, central and eastern Africa. Where records were incomplete or unavailable dead specimens were requested for identification. The responses, however, were rather disappointing. In Zimbabwe, requests were also sent to all provincial extension offices but responses were also unsatisfactory. Table 1 summarizes the information from the postal survey. Whilst correlations of *Z. subfasciatus* and *A. obtectus* with environmental conditions have been suggested in South America (especially altitude linked climatic effects), no similar correlation studies are available for Africa, though some literature and information from our postal survey suggests broad associations with altitude and temperature. It has been documented that optimum temperatures for growth differ between the two species; *A. obtectus* prefers cooler climates (optimum 30°C) at higher elevations, while *Z. subfasciatus* prefers lower altitudes and warmer temperatures (optimum 32.5°C). In South America, the distributions of the two species are clearly defined according to climatic factors; thus, *Z. subfasciatus* is common in tropical zones of Colombia and other countries but is not found in mountainous or subtropical regions of Chile and Mexico, where *A. obtectus* is the main pest. Although, *A. obtectus* is better adapted to cooler environments than *Z. subfaciatus* it is far more successful and found wherever beans are grown in Africa. The distribution of *Z. subfaciatus* appears to be far less defined, and though common in the hot lowlands, detailed surveys in Uganda and Tanzania have shown a much wider distribution, irrespective of altitude and temperature. The most likely influences on distribution of these bruchids in Africa are the distribution of the preferred host (beans) and trade routes in this pulse. Bruchid distribution maps may often also reflect the distribution of active bruchid specialists.

BRUCHID INCIDENCE AND POPULATIONS IN THE FIELD

Two plots (40 x 12 m) planted to Natal Sugar beans on 13/1/91 were monitored for bruchid populations. Twenty meters of every alternate row of each of the two plots were sampled weekly, using a D-vac suction sampler; thus, each 20 m row was sampled every two weeks.

Results

The bruchid species and their numbers sampled are given in Table 2. Whilst populations of *Callosobruchus rhodesianus* and *A. obtectus* were the most numerous, and increased rapidly after pod initiation, few adults of *Bruchidius* spp. and *Z. subfaciatus* were recorded.

AGRONOMIC EVALUATION OF BRUCHID RESISTANT GERMPLASM

A bruchid resistance nursery consisting of 55 'RAZ' lines from CIAT were planted during the 1990/91 season at the Harare Research Station for multiplication of seed, preliminary evaluation of agronomic characteristics and yield potential. The parameters measured were days to first flowering, canopy height, days to 95% maturity and seed yield. The preliminary data given in Table 3 showed large variation between the genotypes. The highest yielding lines were RAZ 13-3, 13-4, 18-1, 19, and 25-3 whilst RAZ 7, 12 and 12-1 produced the lowest yields. The germplasm was planted again in 1991/92 but, due to poor growth because of drought, no records were taken and yields were severely affected.

EVALUATION OF TRADITIONAL GRAIN PROTECTANTS

Laboratory trials

The admixture of non-toxic compounds such as plant products and inert materials is one practical way of dealing with storage pests. A survey of storage methods used by small farmers in Zimbabwe revealed that several traditional methods are currently in use, the most common being admixture of ash and natural plant products. Although insecticides are effective in controlling bruchids, their high cost, un-availability, the danger of resistance building-up, and their safety hazards make alternative control measures important.
One of the major setbacks to the adoption of such treatments in insect control is the bulky nature of the amounts needed to give effective grain protection. However, this technique is still important where lower value crops are concerned and amounts harvested are too low to be economically protected using conventional pesticides.

The purpose of these experiments was to evaluate the efficacy of admixing wood ash, sand, rapoko husks, sunn-hemp seeds and neem leaf powder applied at various rates in protecting beans from bruchid infestation. Experiments were conducted in a constant temperature and humidity room at 26.5°C and 55-60% relative humidity.

Results and discussion

The results (Tables 4a and 4b) show that treatments were effective in reducing insect multiplication and grain damage. The ash treatment was superior to all other substances at all rates of application. The effectiveness of the ash-storage method for legumes (cowpeas and beans) has been confirmed by these studies. While ash provides a physical barrier and restricts insect movement it is also possible that it acts in other ways. Ash provides a sorptive surface in which it may dessicate bruchid eggs, larvae and adults. The ash particles may also clog insect spiracles and trachea causing suffocation. For the other substances, an application rate of at least 1:1 (v/v) was needed to give a significant level of protection. In these 'no choice' experiments neither rapoko husks nor sunn-hemp gave any protection; their claimed repellent effects were not evaluated in this experiment.

Simulated bean storage in clay pots

The effectiveness of ash, sand, vegetable oils and rapoko husks admixed with beans stored in clay pots at ambient conditions was evaluated. The amounts of the substances admixed corresponded to an equivalent volume rate of 0.25:1 (substance: bean) and the oil was applied at a rate of 7.5 ml/kg beans. Each clay pot containing 2 kg of beans was infested with 400 freshly emerged adults. The experiment was replicated three times and performed separately for the two bruchid species. To prevent insects from escaping, the pots were closed with muslin secured by elastic bands.

Results and discussion

The mean numbers of insects that emerged and the percentage grain damage are given in Tables 5a and 5b). The trial clearly demonstrates that the admixtures protect the grain, to varying degrees. Oil treatments were the most efficacious, followed by ash treatments.

CONTROL OF BRUCHIDS WITH NEEM AND VEGETABLE OIL TREATMENTS

Admixture of edible vegetable or neem oils to protect beans from infestation is a common practice in many countries at the small farmer level. For subsistence farmers who store small quantities of beans for home consumption, admixing the grain with edible oils at 5 ml/kg is practical and cost effective. Our survey revealed that the small Zimbabwean farmers were unaware of this method of protecing beans or cowpeas from bruchid infestations. Therefore, experiments were conducted to test the efficacy of two locally produced oils (sunflower and a cotton seed - soya oil blend) and compared with a commercial preparation of neem oil and an insecticide treatment (pirimiphos-methyl at 10 ppm). The oils were tested at 3 rates and evaluated 0 (immediately), 8 and 16 weeks after treatment against both bruchid species. The following parameters were measured: adult mortality, fecundity, egg hatch, F_1 emergence and percentage grain damage.

Results and Discussion

Adult mortality

The mortality of *A. obtectus* and *Z. subfasciatus* after 7 days exposure to freshly treated grain, and treated grain aged for 8 and 16 weeks, is given in Table 6. All fresh oil treatments caused very high mortalities of both species. The lethal effect of vegetable oils decreased significantly with time, while neem oil was still active 16 weeks after application.

Fecundity and egg hatch

The mean numbers of eggs laid and percentage egg hatch in *Z. subfasciatus* are given in Tables 7a and 7b, respectively.
Oil treatments were significant in reducing both the number of eggs laid and hatched at the three periods investigated. For freshly treated beans in all the oil treatments, oviposition was low because of high adult mortality. Neem oil treatments resulted in complete protection of beans. There was no evidence of differences between dosage after the vegetable oils had been aged for 8 and 16 weeks.

Adult emergence

The numbers of adults emerged and percentage survival of *Z. subfasciatus* are given in Table 8 and the effect of oil treatments on emergence of *A. obtectus* is shown in Table 9.

Percentage damage

The percentage damage incurred by *A. obtectus* and *Z. subfasciatus* after one generation in the different treatments are compared in Tables 10a and 10b, respectively. The results of these experiments show that the oil treatments caused a significant reduction in oviposition, egg hatching, mortality, and percentage damage. Neem oil was the most effective, at all dosage rates and storage periods investigated. There was a significant decline in activity of vegetable oils after 8-16 weeks compared to fresh oil deposits. Performance of both vegetable oils were similar.

SCREENING GERMPLASM FOR RESISTANCE

The RAZ lines from CIAT were multiplied over two seasons to obtain enough seed for resistance tests against *A. obtectus* and *Z. subfasciatus*. The preliminary results are presented here.

Results and Discussion

The results (Table 11) suggest that resistance was expressed in the following ways: i) prolonged development period;
ii) mortality of larvae within the seed (antibiosis); iii) mortality in the pupal stage; iv) failure of adults to emerge (although 'windows' appeared); and v) reduction in F_1 adult weight.

CONTROL OF BRUCHIDS WITH SORPTIVE DUSTS (Dryacide)

"Dryacide" is a commercial formulation of a sorptive dust using diatomaceous earth and silica aerogels. This product is effective against a wide range of stored product pests. In this study 0.5, 1.0 and 2 g of dryacide per kilogram of beans were tested against *Z. subfasciatus*. Treated beans were infested with insects immediately after treatment, and after 8 weeks in storage. The mortality of adults, progeny emergence and damage were measured.

Results and Discussion

The results confirm that dryacide is an effective grain protectant (Table 12) and would be appropriate for the small farmer who usually has no specialized storage facilities, little money with which to buy chemical pesticides and often lacks knowledge of the proper use of toxic pesticides.

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Table 1. Distribution of bean bruchids in Africa.

Country	Respondent	Species	Comments
Angola	C. Camarada	*A. obtectus*	No countrywide information, records from Huambo - mean temp. 19°C, altitude 1700 m
Burkina Faso	C. Dabire	No records	Beans unimportant but cowpeas widespread; *C. maculatus* and *B. atrolineatus* common
Namibia	C. Roberts	No records	-
Kenya	F. Olubayo	*A. obtectus* *Z. subfasciatus*	Widespread, restricted to Ugandan border (unconfirmed verbal reports)
	S. Kyamanywa	*Z. subfasciatus*	Coastal Mombassa region; lowlands
	B. Tengecho	*A. obtectus*	National Museum records, no records of *Zabrotes*
Tanzania	S. Nchimbi	*Z. subfasciatus* *A. obtectus*	Surveys in Morogoro, Dodoma and Arusha; altitude 1200 m, *Zabrotes* species.
Zimbabwe	P. Chinwada	*A. obtectus*	*Acanthoscelides* most widespread,
	D. Giga	*Z. subfasciatus*	only 1 sample of *Zabrotes* collected in surveys.
Malawi	E. Muwali	*A. obtectus*	Beans grown in highlands; temp 17-27°C, altitude 900-1700 m; rainfall 600-1000 mm No records of *Zabrotes*, but uncertain of presence
Zambia	S. Sithanan-tham	*A. obtectus*	Widespread

Table 1 cont.

Country	Respondent	Species	Comments
Rwanda	I. Butare	*A. obtectus*	Less important but most common in 'hot regions' of lowlands in East and South of country at altitudes of 1000-1300 m
Lesotho	A. Ansari	*A. obtectus*	Widespread
Swaziland	-	*A. obtectus*	Walker (1979)
Ethiopia	-	*Z. subfasciatus*	Decele (1980)
Mozambique	P. Segeren	*Z. subfasciatus* *A. obtectus*	Museum records of both species including lowland areas. *Acanthoscelides* more widespread.
Uganda	S. Nahdy	*Z. subfasciatus* *A. obtectus*	Both species widespread in Uganda and occur together. *Zabrotes* is relatively new in Uganda. Detailed survey information on species composition available.

Table 2. The bruchid species and populations sampled with time[1].

Date	*Acanthoscelides obtectus*	*Zabrotes subfasciatus*	*Callosobruchus maculatus*	*Callosobruchus rhodesianus*	*Bruchidius* spp.
31/1/92	3	0	0	0	0
7/2	8	0	1	0	1
14/2	0	0	3	3	1
21/2	2	0	0	10	0
28/2	8	0	0	32	0
6/3	1	0	0	57	5
13/3	8	0	2	41	4
23/3	9	0	0	31	0
27/3	23	0	0	52	0
3/4 (harvest)	31	0	0	19	0

[1] Presumably in Harare, at approximately 1500 masl and latitude about 17°48'S (Ed.)

Table 3. Agronomic evaluation of 'RAZ' lines - Bruchid resistance nursery

Line	1st flowering (days)	Canopy height (cm)	95% maturity (days)	Seed yield (g)
RAZ 4-2	39	43	81	96.1
5	39	42	81	146.1
6	39	43	81	71.2
7	37	31	81	41.0
8	46	38	102	152.1
9	46	38	92	115.1
9-1	42	38	104	212.6
9-2	47	37	102	162.2
9-4	50	35	104	113.3
10	39	42	89	135.2
11	39	30	95	151.1
11-1	43	33	92	153.5
12	46	37	97	39.2
12-1	53	45	97	39.7
12-4	46	43	97	140.8
13	46	42	89	140.0
13-1	43	40	89	80.7
13-2	42	45	89	172.5
13-3	39	45	89	206.7
13-4	46	43	89	254.2
13-5	46	42	89	123.2
13-6	46	47	89	111.7
14	39	43	89	125.2
15	42	43	95	141.4
16	39	42	92	106.1
17	39	42	85	94.3
17-1	39	40	89	135.9
17-2	39	28	85	70.1
17-3	39	37	89	152.5
17-5	39	45	85	97.2
17-6	39	42	85	121.9
17-7	39	32	85	56.9
18	42	45	92	148.7
18-1	39	47	95	185.1
19	42	42	89	176.8
20-1	39	45	81	66.2
20-2	39	45	81	73.8
21	42	45	85	113.3
22	39	25	81	88.7
24	37	40	83	63.2
24-1	39	33	89	76.9
24-2	39	35	89	144.6
24-3	37	47	89	117.8

Table 3 contd.

Line	1st flowering (days)	Canopy height (cm)	95% maturity (day)	Seed yield (g)
RAZ 24-4	37	42	89	102.2
24-5	37	40	89	80.0
25	42	48	95	157.5
25-1	47	45	95	119.1
25-2	42	50	97	150.6
25-3	46	45	97	191.6
25-8	46	48	95	144.7
27	39	47	85	105.0
28	39	48	85	82.1
29	30	43	89	141.1
30	46	42	97	192.9

1 m x 1 m plots; spacing 45 cm x 7.5 cm.

Table 4a. The effect of admixing different substances with beans at various rates on damage and development of *Z. subfasciatus*

Rate (v/v)	Substance	Mean number of F_1 emerged	Mean % damage
0:1	Control	148.2	84.5
0.25:1	rapoko	141.0	45.5
	neem	156.6	49.3
	ash	102.4	35.5
	sunhemp	153.6	73.5
	sand	128.0	49.6
0.5:1	rapoko	124.0	22.6
	neem	99.6	15.0
	ash	15.4	5.2
	sunhemp	136.8	61.8
	sand	50.4	17.8
1:1	rapoko	81.0	10.3
	neem	27.0	2.5
	ash	7.8	1.8
	sunhemp	110.2	29.1
	sand	48.8	6.1
S.E.D between treatment means		0.94	0.06

Table 4b. The effect of admixing different substances with beans at various rates on damage and development of *A. obtectus.*

Rate (v/v)	Substance	Mean number of F_1 emerged	Mean % damage
0:1	Control	120.6	64.6
0.25:1	ash	17.2	9.5
	sand	101.0	47.3
	rapoko	120.8	53.2
	neem	135.8	56.3
	sunhemp	77.4	47.6
0:5:1	ash	0	0.1
	sand	86.4	31.5
	rapoko	24.3	15.8
	neem	81.4	30.1
	sunhemp	82.2	55.5
1:1	ash	3.2	0.1
	sand	18.2	7.0
	rapoko	7.4	7.5
	neem	7.2	5.1
	sunhemp	91.2	51.5
S.E.D between treatment means		1.19	0.08

Table 5a. Effect of admixing different substances on damage and in development of *Z. subfasciatus* in clay pot trials.

Treatment	Application rate per kg beans	Number F_1 emergents	% Damage
Control	-	3167.0	66.4
oil	7.5 ml	0	0
ash	220.5 g	761.3	6.1
sand	500.2 g	28243	28.4
rapoko	35.3 g	2852.3	37.7
SED		2.28	0.06

Table 5b. Effect of admixing different substances on damage and in development of *A. obtectus* in clay pot trials.

Treatment Damage	Application rate per kg beans	Number F_1 emergents	%
Control	-	3662.6	42.8
oil	7.5 ml	0	0
ash	220.5 g	33.0	0.8
sand	500.2 g	2929.7	27.9
rapoko	35.3 g	2588.7	25.4
SED		8.87	0.07

Table 6a. Percentage mortality of *Z. subfasciatus* adults exposed to grain treated at 0,8 and 16 weeks before infestation

Dose ml/kg	Treatment	age of deposit (weeks)		
		0	8	16
	Control	6.0	4.0	6.0
10 ppm	pirimiphos-methyl	100	100	100
	sunflower	89.4	8.3	6.4
2.5	cotton + soya	93.6	11.3	6.3
	neem	100	100	85.1
	sunflower	100	10.4	5.5
5.0	cotton + soya	100	14.6	5.3
	neem	100	100	93.9
7.5	sunflower	100	5.8	4.7
	cotton + soya	100	11.3	6.9
	neem	100	100	87.8

Table 6b. Percentage mortality of *A. obtectus* adults exposed to grain treated at 0,8 and 16 weeks before infestation

Dose ml/kg	Treatment	age of deposit (weeks) 0	8	16
-	control	4.0	2.0	6.0
10ppm	pirimiphos-methyl	100	100	100
	sunflower	95.8	6.9	0
2.5	cotton + soya	100	3.3	0
	neem	100	100	83.0
	sunflower	100	1.6	0
5.0	cotton + soya	100	8.7	0
	neem	100	100	95.7
	sunflower	100	3.3	0
7.5	cotton + soya	100	6.9	0
	neem	100	100	97.9

Table 7a. The effect of oil treatments on the number of eggs laid by *Z. subfasciatus*

Dose ml/kg	Treatment	age of deposit (weeks) 0	8	16
-	control	232.8	183.4	183.2
10ppm	pirimiphos-methyl	0	0	0
	sunflower	74	117.2	183.2
2.5	cotton + soya	66.6	119.4	106.4
	neem	0	0	8.2
5.0	sunflower	0	100.4	150.8
	cotton + soya	0	147.0	132.4
	neem	0	0	0.2
7.5	sunflower	0	110.6	92.8
	cotton + soya	0	144.6	134.4
	neem	0	0	0

Table 7b. THe effect of oil treatments on percentage egg hatch in *Z. subfasciatus*.

Dose ml/kg	Treatment	age of deposit (weeks)		
		0	8	16
-	control	90.0	84.1	79.8
10ppm	pirimiphos-methyl	0	0	0
2.5	sunflower	10.9	34.6	61.5
	cotton + soya	9.5	44.8	47.2
	neem	0	0	0
5.0	sunflower	0	39.4	68.7
	cotton + soya	0	29.2	28.2
	neem	0	0	0
7.5	sunflower	0	28.1	55.6
	cotton + soya	0	21.3	41.5
	neem	0	0	0

Table 8a. Effect of oil treatments on adult emergence of *Z. subfasciatus*

Dose ml/kg	Treatment	age of deposit (weeks)		
		0	8	16
-	control	125.6	124.0	128.2
	sunflower	4.8	9.4	25.4
2.5	cotton + soya	2.4	16.4	27.4
	neem	0	0	0
	sunflower	0	8.2	8.2
5.0	cotton + soya	0	6.8	11.2
	neem	0	0	0
	sunflower	0	1.6	3.0
7.5	cotton + soya	0	0.2	2.0
	neem	0	0	0

Table 8b. Effect of oil treatments on percent survival* of *Z. subfasciatus*.

Dose ml/kg	Treatment	age of deposit (weeks)		
		0	8	16
-	control	59.3	80.4	87.0
	sunflower	62.3	29.9	34.6
2.5	cotton + soya	32.2	22.3	39.4
	neem	0	0	0
	sunflower	0	14.2	12.0
5.0	cotton + soya	0	13.6	25.9
	neem	0	0	0
	sunflower	0	5.8	4.6
7.5	cotton + soya	0	0.5	5.5
	neem	0	0	0

*Total no. of eggs laid/no. of adults emerged.

Table 9. Effect of oil treatments on number of adult *A. obtectus* emerged.

Dosage ml/kg	Treatment	age of deposit (weeks)		
		0	8	16
-	control	78.4	53.0	51.0
	sunflower	0	2.8	8.4
2.5	cotton + soya	2.6	1.2	6.2
	neem	0	0	0
	sunflower	0	0.4	0.2
5.0	cotton + soya	0	10.6	6.8
	neem	0	0	0
	sunflower	0	1.0	3.6
7.5	cotton + soya	0	6.4	12.6
	neem	0	0	0

Table 10a. Effect of oil treatments on percentage damage by *Z. subfasciatus*

Dose ml/kg	Treatment	age of deposit (weeks) 0	8	16
-	control	72.7	78.7	79.7
	sunflower	0	6.5	12.2
2.5	cotton + soya	3.9	8.2	15.1
	neem	1.8	0	0
	sunflower	0	5.7	5.1
5.0	cotton + soya	0	4.5	7.8
	neem	0	0	0
	sunflower	0	2.1	2.1
7.5	cotton + soya	0	0.4	1.4
	neem	0	0	0

Table 10b. Effect of oil treatments on percentage damage by *A. obtectus*.

Dose ml/kg	Treatment	age of deposit (weeks) 0	8	16
-	control	50.3	39.4	40.3
	sunflower	0	3.7	9.0
2.5	cotton + soya	1.1	1.5	4.3
	neem	0	0	0
	sunflower	0	0.8	0.4
5.0	cotton + soya	0	6.9	4.7
	neem	0	0	0
	sunflower	0	1.1	4.4
7.5	cotton + soya	0	3.6	9.1
	neem	0	0	0

Table 11. Screening results of some 'RAZ' lines to *Z. subfasciatus*.

Accession	No. eggs	F_1	%F_1 Emergence	Develop[1] time (days)
Natal sugar (check)	191.6	160.8	84.1	29.0
RAZ9-1	175.2	15.4	8.5	45.0
9-2	168.4	12.2	8.1	41.2
10	195.8	8.2	4.2	48.6
11	168.8	0.6	0.3	50.3
12	193.0	7.6	3.9	47.8
13	139.8	7.6	5.1	48.2
13-1	171.4	5.2	3.1	47.4
13-2	172.6	4.4	2.6	47.8
13-3	169.2	4.0	2.5	50.8
13-4	146.2	0.2	0.1	70.0
13-5	163.0	0.2	0.1	47.0
13-6	144.2	4.0	2.8	50.2
14	175.0	7.6	4.4	44.4
14-1	187.0	8.8	5.0	48.4
15	175.0	11.2	6.3	43.8
17	170.2	2.0	1.2	51.2
17-1	170.8	3.6	2.1	53.6
17-2	178.0	5.0	2.8	48.6
17-5	165.0	3.4	2.0	39.6
17-7	187.0	14.0	7.6	45.8
18	175.4	4.0	2.2	52.8
18-1	197.8	1.6	0.7	51.3
19	169.6	2.4	1.4	45.8
20-1	158.2	0.4	0.3	58.0
20-2	170.0	22.0	13.0	44.2
21	175.2	12.0	6.8	48.2
22	169.0	9.6	5.6	55.2
24-1	177.0	4.0	2.3	52.4
24-3	175.6	5.0	2.9	51.2
24-5	188.8	2.4	1.2	49.0
24-6	150.8	1.6	1.0	54.0
28	142.0	9.2	6.4	47.8
29	153.6	16.0	10.6	46.8
30	166.2	7.4	4.7	47.8

Table 12. The effect of a sorptive dust on *Z. subfasciatus*.

	Control	Application rate (g/kg) 0.5	1.0	2.0
<u>0 weeks</u>				
Per cent mortality	2.0	98.0	100	100
F_1 emergents	132.0	7.4	0	0
Per cent damage	81.4	4.6	0	0
<u>8 weeks</u>				
Per cent mortality	0	100	100	100
F_1 emergents	124.0	5.2	0	0
Per cent damage	82.0	6.3	0	0

STUDIES ON THE CONTROL OF THE BEAN BRUCHIDS *Acanthoscelides obtectus* (Say) and *Zabrotes subfasciatus* (Boheman) (COLEOPTERA : BRUCHIDAE) IN THE EAST AFRICAN REGION.

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ABSTRACT

Bean bruchid research in eastern Africa was initiated with CIAT assistance in 1990. Studies were conducted to complement those being conducted elsewhere in Africa. Bruchid distribution was studied and findings presented in a bean research workshop in Nairobi in 1990. Farmers' perception of bruchid damage and control was investigated in representative agro-ecological zones of Uganda. A line of Phaseolus vulgaris (RAZ 2), bred for resistance to Z. subfasciatus, was tested. Compared to the local susceptible cultivars, a significantly lower number of insects emerged from RAZ 2 which showed negligible seed damage and weight loss. Two methods of solar disinfestation were compared on beans infested with Acanthoscelides obtectus. These were direct exposure to the sun (T1) and enhanced heat (T2). There was a greater build-up of temperature and a higher adult mortality in T2, though in T1 there was 100% adult escape. After an incubation period of 5 weeks, there was no significant difference in total adult emergence between T1 and T2. Low adult emergence in T2 was attributed to higher mortality due to solar heat, and in T1 to the exclusion effect on the adults and eggs. The possibility of controlling A. obtectus by repeated sieving was investigated. Repeated sieving of stored beans every five days over a period of 50 days was found to give excellent control. Three A. obtectus management methods (bean sieving, sunning and corn oil treatment) were tested on-farm at 5 different homesteads. The weekly sieving and sunning regimes over a period of 5 weeks gave the best results. Oil treatment at a rate of 5 ml per kg, though having lower infestation and damage levels than controls, could not maintain its effectiveness with time. Possible alternate host plants of A. obtectus were studied. Of the 25 different legume seeds collected from within Uganda, only five species (Vigna unguiculata, Cajanus cajan, Phaseolus acutifolius and two unidentified species) were capable of being infested by A. obtectus. During sexing of A. obtectus, the colour and pattern of the pygidium was found to be an accurate and easy method separating males from females. In collaboration with the bean research network of CIAT in Africa, a bean bruchid travelling workshop and survey was conducted in 1992 in Uganda, Tanzania and Zimbabwe, with the aim of investigating the distribution patterns, damage levels and control methods used against the two bruchids, and to determine

farmers' perception of bruchid damage.

INTRODUCTION

The two bruchid species *A. obtectus* and *Z. subfasciatus* are the most important pests of stored beans. These cause damage, weight loss, and a reduction in quality and seed viability. Losses in East Africa have been estimated at between 30% and 73% (Karel & Autrique, 1989). In Uganda, losses have been put at 3% and 8% in storage for 3 and 6 months, respectively (Silim et al., 1991). *A. obtectus* has been found to be the predominant species in the cooler regions, while *Z. subfasciatus* is the commonest species in warmer environments (van Schoonhoven et al., 1986). Infestation by *A. obtectus* begins in the field and intensifies in storage whereas *Z. subfasciatus* infestation often begins in storage (Silim, 1990). Oviposition by *A. obtectus* occurs on pods under field conditions, while in grain eggs are laid loosely among the seeds. *Z. subfasciatus* glues the eggs on to the grain.

The most publicised method of bruchid control is the use of insecticides, but these are seldom used by subsistence farmers. In addition, dust formulations have limited shelf- life and are prone to user abuse. Other control methods include bean resistance, use of oils and bean tumbling (Quentin et al., 1991). Use of oils and bean tumbling, though found successful experimentally, may have limited adaptability due to their costs and inconvenience, respectively. Alternate on-farm control measures which are safe and reliable are therefore needed. The focus of this research was placed on practices found on-farm. These include solar heat treatment, bean sieving methods, and locally available protectants. On-farm trials were conducted to establish the efficacy of sunning, sieving and vegetable oils on *A. obtectus* infestation at the on-farm level.

MATERIALS AND METHODS

Farmers' perception of damage and control

A survey was conducted to investigate farmers' perception of bruchid damage and control methods used, and to assess damage/loss levels in Uganda. 130 farmers in nine representative districts in the four agro-ecological zones of Uganda were selected for the survey. A questionnaire was prepared for the farmers' response. Bean samples were collected (500 g) for analysis of damage, weight loss and bruchid identification.

Resistance to *Z. subfasciatus*

The four bean cultivars tested (RAZ 2, EMP 175, K20 and White haricot) were equally infested with four sexed pairs of newly emerged insects and incubated for four months.

Solar heat disinfestation

Equal batches of K20 were infested twice with 40 pairs of *A. obtectus*. The first infestation allowed an incubation of 20 days after which all insects were removed. In the second infestation, no adult was removed after 7 days incubation. Treatments were: T1 (open tray) and T2 (top covered with clear polyethylene and bottom with black polyethylene sheet).
Trays were placed in the sun and seed temperature was taken at hourly intervals. Thereafter, counts were made of total numbers of live/dead adults, and adult counts were made weekly for 5 weeks.

Bean sieving

The effect of sequential sieving of bean seed on the damage to cultivar K20 infested with *A. obtectus* was investigated using two levels of infestation. A light initial infestation was obtained by giving no 'pre-storage' treatment, and a heavy infestation was achieved by subjecting seed to a period of 50 days pre-storage. Sieving was done at seven day intervals for 49 days.

Other control methods

Other control methods currently being investigated include the use of 'botanicals' including preparations made from *Gynandropsis gynandra, Melia azedarach* and shea butter.

Alternate host plants of *A. obtectus*

Seeds of a range of legume species were collected from throughout Uganda. Species included the following : *Acacia elatior, Bauhinia punctata, Caesalpinia pulcherrima, Cajanus cajan, Cassia petersiana, Cassia grandis, Cassia spectabilis, Cassia tora, Centrosema pubescens, Crotalaria incana, Desmodium lasiocarpum, Glycine javanica (= Neonotonia wightii), Lablab purpureus, Leucaena leucocephala, Macroptilium lathyroides, Macroptilium atropurpureum, Phaseolus acutifolius, Piliostigma thonningii, Rhynchosia* spp., *Vigna unguiculata* and two unidentified species. Seed were incubated for a month during which insect emergence was noted. Seed were then disinfested before reinfestation with eggs of *A. obtectus*, and incubated until adult emergence.

A method of sexing *A. obtectus*

The significance of the colour, density and patterns of bristles on the pygidium of *A. obtectus* adults was investigated. "Variation 1", with adult populations having brown pygidium, were separated from "variation 2" populations, with brown and grey patterns on the pygidium, before sexing using male genitalia.

Travelling workshop and survey

In collaboration with SADCC, Great Lakes and CIAT scientists, a travelling workshop was organized and undertaken in Uganda, Tanzania and Zimbabwe in September 1992. It included entomologists, agronomists and breeders from CIAT, Uganda, Tanzania, Burundi, Zimbabwe and Ethiopia. The aim of the survey was to investigate farmers' perception of bruchid damage and control, to measure actual damage levels and to determine species composition.

RESULTS AND DISCUSSION

Farmers' perception of damage and control

The majority of the respondents were males in the age range of 20 to over 50 years and had been growing beans for 10 to over 30 years, depending on individual age. Though two growing seasons were identified in all the bean growing areas, 34% of the farmers, mostly in agro-ecological zone 111, grew beans in only one of the seasons. Bean production per family ranged between 50-300 kg per season. Harvested beans were sun dried and threshed. Bean seeds were redried and stored for either home consumption, seed or for sale. Storage duration ranged from 1-4 months (41%), 5-8 months (90%) and for up to one year (9.0%). The bruchids were identified as the major storage problem. Most farmers (56%) thought that some bean varieties are more susceptible to bruchid infestation than others. The smaller seeded bean varieties were considered more resistant. The commonest bruchid control strategy used by farmers was regular re-drying in the sun. Re-infestation after solar heat treatment was however considered rapid. Other bruchid control methods used, other than chemical, included tobacco leaves, wood ash, banana juice and red pepper. Some 27% of farmers thought nothing could be done to control bruchids. The only method considered very effective was chemical control. Among the chemicals used were Actellic, Malathion, D.D.T and various other non-storage insecticides. Most traditional methods being used were considered effectual and had other problems associated with their use, like difficulty in cooking, eating and cleaning.

Resistance to *Z. subfasciatus*

Results (Table 1) clearly indicate that there are highly significant differences between varieties in terms of adult emergence. Adult emergence from RAZ 2 after four months remained negligible. Results confirm that RAZ 2 is highly resistant to *Z. subfasciatus;* the degree of resistance was consistent with previous laboratory assessments (Cardona et al., 1990). The level of resistance incorporated in RAZ 2 provides an adequate level of crop protection against *Z. subfasciatus,* and is therefore recommended for use in situations where conventional pest control procedures cannot be utilised.

Solar heat disinfestation

Temperatures of 640-650 C were recorded in the T2 treatment while the highest recorded temperature in T1 was 45.5 C. The adults in

T1 had all escaped while 90.2% died in treatment T2; 5.6% mortality was recorded in the control (TO). After 5 weeks incubation, mean adult emergence in T1 and T2 were 16.7% and 15.8%, respectively, with 100% in the control (Table 2).

Two factors were considered responsible for the overall reduction in *A. obtectus* emergence in T1 and T2 : direct mortality due to solar heat in T2; and the exclusion effect whereby adults escaped due to heat and sun glare, while at the same time eggs loosely laid among the beans were naturally sieved off. These suggest that both the direct killing effect of the sun and the exclusion effect due to sieving may play a role in the control of *A. obtectus*.

Bean sieving

Results (Table 3) demonstrate that the sieving regime gives total control of *A. obtectus*, irrespective of the duration of storage and of previous infestation. Very heavy damage was recorded in un-sieved beans. This method would be ideal for subsistence farmers where trays are already used for drying and could be combined with an appropriate solar disinfestation to considerably extend storage durations by reducing damage by *A. obtectus*.

Alternate host plants

In most of the plant species tested, the larvae died soon after penetration. However, in *Macroptilium atropurpureum* and *M. lathyroides* there was larval development but, due to the small size of the seeds, the food supply within the seed was exhausted within 28 days and most larvae/pupae died; a few very small adults emerged but they died soon after emergence. Complete development of the insects and adult emergence was noted in *Cajanus cajan, Vigna unguiculata, Phaseolus acutifolius* and two unidentified legume species.

Sexing *A. obtectus*

The results of the dissection (Table 4) indicate that the variations in the hues and patterns of coloration on the pygidium is a form of sexual dimorphism that could be used for easy sexing of *A. obtectus*. Variation 1 is composed predominantly of males and variation 2 of females.

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Table 1. Storage test results in Uganda, 120 days after infestation.

Bean Variety	Adult emergence, total no. (a)	Damage, % (b)
K 20	1029.8 (6.94)	16.4 (0.41)
RAZ 2	9.6 (2.26)	0.0 (0.00)
White haricot	1173.6 (7.06)	16.0 (0.37)
EMP 175	740.0 (6.60)	4.4 (0.20)

a/b Parentheses signify log and arcsin x/100 transformations, respectively.

Table 2. Mortality of *A. obtectus* in two solar treatment methods.

Treatment	Adult mortality (%)	Escapes (%)
To (control)	5.6	0.0
T1 (open tray)	0.0	100.0
T2 (covered)	90.2	0.0

Table 3. Effect of sieving and level of initial infestation with *A. obtectus* on damage in bean seed stored for varying periods.

Storage period (days)	Damage (%) Initial infestation light		Inititalinfestation heavy	
	sieved	unsieved	sieved	unsieved
0	0.00	0.00	8.75	9.26
50	0.02	0.40	13.62	62.70
110	0.20	7.67	13.47	69.67
170	0.05	60.40	13.57	88.80

Table 4. Sex of insect populations for each of the pygidium variations

Observer	Insects with colour variation 1		Insects with colour variation 2	
	males	females	males	females
1	33	2	2	62
2	54	1	0	45
3	49	0	0	51
4	49	2	1	48
Totals	185	5	3	206
Composition %	97.4	2.6	1.4	98.6

PROGRESS IN BEAN BRUCHID MANAGEMENT

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ABSTRACT

To establish effective control measures against bean bruchids, a series of experiments involving survey, botanical control and varietal resistance were conducted. The results of the survey indicated that the most important insects attacking stored beans were Acanthoscelides obtectus (Say) and Zabrotes subfasciatus (Boheman). Bruchid damage ranged from 0-38% for the surveyed villages and corresponding seed weight losses ranged from 0 to 3.2%. Among the botanicals tested for protection of stored beans, neem seed powder followed by pepper tree (Schinus molle) and persian lilac (Melia azedarach) seed powder protected the bean seeds from bean bruchid (Z. subfasciatus) attack for 120 days. Protection with neem seed powder is comparable to the standard insecticide pirimiphos methyl; these two treatments gave complete control of bruchids. Results with varietal resistance indicated that 15 varieties showed a low percentage of damaged seed free of emergence holes. Number of eggs per seed cannot be used as a single criterion for resistance, since some of the varieties yielded a large number of eggs, though they did not show any damage.

INTRODUCTION

Haricot bean, *Phaseolus vulgaris* L. is one of the most important pulse crops grown in Ethiopia, either for local consumption as a source of protein or as an export crop for earning foreign exchange. The main production areas of haricot bean lie between altitudes 1400-2000 m for rainfed agriculture, and 700 m and above under irrigated conditions (Ohlander, 1980). The bulk of haricot bean is consumed locally, but a certain proportion is exported. From 1973 to 1987, an average of nearly 24,000 metric tons of haricot bean was exported with annual revenue of more than 19,000,000 birr. Haricot bean accounted for 37 million birr or 84.1% of 44 million birr earned from the export of pulses and oilseeds during the 1989/90 fiscal year (Ayele, 1990). However, the average yield of haricot bean is less than one ton/ha (CSA, 1987). Several species of insects, fungi, rodents, birds and mites are associated with food grain storage. Of the 10% post- harvest food grain losses in developing countries, insects alone are responsible for about 2.5% losses in grain stored for 6 months (Jiliani and Saxena, 1988). Among the various insect

pests of stored grain products, *Callosobruchus chinensis* (L), *C. maculatus* (F), *Acanthoscelids obtectus* (Say) and *Zabrotes subfasciatus* (Boheman) are the most important insect pests of grain legumes. These insects belong to the family Bruchidae which are prolific and rapid in their breeding and can quickly cause a serious reduction in the nutritive value of stored seed (Parkin and Bills, 1955). In Africa, storage pests are quoted to cause losses of 10-15% and 23-80% damage after 2-4 months of storage (Odogola, 1986). Despite the fact that insects as stored pests have caused severe storage losses, stored product pests have not received sufficient attention as a research priority in Ethiopia. Consequently, little information is available as to the exact identity of the species, their relative importance and control. This paper highlights recent progress in research regarding survey, botanical control and varietal resistance of bruchids.

MATERIALS AND METHODS

Survey

A survey of haricot bean storage pests was conducted in the central zone of Ethiopia. Twenty sites and five stores at each site were selected at random. Samples of about 250 g haricot bean were taken from storage, kept in labelled cloth bags, and brought to the laboratory at Nazareth Research Centre (NRC) of IAR where assessment of damaged grains and counts of bruchids were made. Percent damage, weight loss and insect species were determined.

Botanical control

Seeds of haricot bean cv. Diacol Calima were obtained from the lowland pulse programme of NRC and multiplied at the centre's farm. After harvest, the seeds were kept in a refrigerator at 0°C for 7 days to disinfest them from any prior infestation.
The grain moisture content of the seed was allowed to equilibrate for 3 weeks. After disinfestation, 150 g of the grain was placed in each of 120 bottle jars (60 mm in diameter and 110 mm in height) covered with muslin cloth to prevent entrance of insects.
The test plants' flowers, leaves and seeds were collected from around Nazareth, except for neem that was obtained from Dire Dawa forestry department. The plant materials were dried, then ground into fine powder using a mortar and pestle. Pirimiphos-methyl was used as a standard check. Fifteen grams of the ground plant material was added to each bottle. In all cases (except pirimiphos-methyl) 10 parts of the material was mixed with 100 parts (w/w) of grain. Pirimiphos-methyl was applied at 4 ppm. The ten treatments, including an untreated check are presented in Table

1. Each treatment with four observation times (24 hours, 30, 60 and 90 days after treatment) was replicated three times, thus a total of 120 jars (10 treatments x 3 replications x 4 observation times) were filled each with 150 g of grain. The desired amount of each test material was applied to the grain and mixed thoroughly. At each observation time, 30 bottles were withdrawn. Ten pairs of the adult test insects (0-24 h old) *Zabrotes subfasciatus* were introduced to each bottle, starting from 24 h after treatment. The sexes of adults of *Z. subfasciatus* were determined by the colour of the elytra (Halstead, 1963) prior to introduction of each batch. Thereafter, the bottle was covered with muslin cloth which served as ventilation and prevention of entrance and escape of insects. The grain was then sieved, adult insects were discarded and the number of eggs laid were counted. The seeds were returned to their respective jars and kept for assessment of damage due to F_1 progeny. The experiment was laid out in a completely randomized design with three replications.

Varietal resistance

One hundred genotypes of *Phaseolus vulgaris* from CIAT and the breeding programme of NRC were used. The seeds were disinfested and equilibrated as described above. A no-choice test of resistance was used. Fifty sound seeds of each accession were placed in a small bottle (50 mm in diameter and 110 mm in height). The bottles with seeds were infested with seven pairs of newly emerged *Z. subfasciatus* (0-24 h old). Bottles were then covered with muslin cloth. Two weeks after introduction, the parent insects were removed and the total number of eggs laid on the seed in each bottle was counted. Evaluations were made again one month later, on appearance of emergence windows. The main criteria used for evaluating the resistance of the materials included the number of eggs, the number of adults emerged, and the number of exit holes per 50 seeds.

RESULTS AND DISCUSSION

Survey

The main cultivar of haricot bean produced in the survey area is the white pea bean, Mexican 142. In a survey of 100 stores in this area, the period of bean storage ranged from 7-9 months. The major stored bean pests observed during our survey were the two bruchid species, *Acanthoscelides obtectus* and *Zabrotes subfasciatus*.

Dry beans are harvested by uprooting and are threshed, either by beating with a stick or trampling by animals, then winnowed and kept in storage. Types of storage container included sacks, tins and, locally, "gotera" and "debignet". The infestation and damage became more serious two to three months after storage. In most cases, farmers do not treat against bruchids. However, in some areas they use lindane (2 match boxes per quintal) placed in layers. Rodents often destroy storage structures and termites build their mounds inside them.

Assessments were made in the laboratory to determine the loss caused by bean bruchids. In the area surveyed, bruchid damage ranged from 0-80% and loss was assessed to be as much as 3.2%. Damaged seeds were usually discarded.

Botanical control

The plant materials, except neem seed powder, protected less against oviposition of *Z. subfasciatus* than did the standard insecticide pirimiphos-methyl (Figure 1.). Both pirimiphos methyl and neem seed powder were effective up to 120 days after treatment (DAT). These two materials were topically toxic, indicated by their antioviposition effect, and a seven-day exposure of the adult to neem seed powder and pirimiphos-methyl caused 85-100% adult mortality. Bean seed treated either with pirimiphos-methyl or neem had less bruchid damage than seed treated with other plant powders. However, bean seed treated with seed powders prepared from either the pepper tree (*Schinus molle*) or persian lilac (*Melia azedarach)* were less damaged than seed in the remaining treatments, up to 120 DAT.

In all treatments, the number of eggs and damaged seeds seemed to increase with storage time, but there was no indication of degradation of the materials since the differences were small.

Varietal resistance

Resistance of the haricot bean varieties to *Z. subfasciatus,* as indicated by oviposition preference and number of holes produced by emerging adults, are summarized in Figure 2. Least oviposition was observed for the genotypes RAZ-8 (4 eggs/50 seeds) followed by Brown Speckled and RAZ 20-1 with 11 and 16 eggs/50 seeds, respectively. The varieties RAZ 1 followed by ICA 15541 and Awash 1 were preferred genotypes for oviposition.

Varieties RAZ-8, Brown Speckled, RAZ 20-1, RAZ 20, RAZ 13-5, RAZ 6, RAZ 21, RAZ 33, RAZ 11, RAZ 17-3, RAZ 18-1, RAZ 7, RAZ 17-1, RAZ 22 and RAZ 1 showed the least number of emergence holes (zero) indicating that these varieties were the most resistant. Large numbers of emergence holes (maximum damage) were found in almost all varieties received from the bean breeding program of NRC, including both released varieties and advanced breeding lines in the pipeline for release. The varieties with high levels of damage included ICA 15541, Awash 1 and HAL 5, with 193, 159 and 153 holes /50 seeds, respectively, indicating high levels of susceptibility.

These results indicate that some of the varieties with a large number of eggs had either no exit holes or a very few holes. van Schoonhoven et al. (1983) reported that, under no-choice test, *Z. subfasciatus* adults oviposited on seed of all accessions, but in free-choice test, adults of *Z. subfasciatus* preferred to oviposit on seeds of susceptible varieties. Consequently, in a no-choice test, the number of eggs is not a useful parameter alone for identifying seed resistance. The main features that were observed in seed of resistant varieties were delay in the developmental period and few or no emergence holes. These are in agreement with the findings of Ahmed et al. (1989), Cardona et al. (1989), Gatehouse et al. (1987), and van Schoonhoven et al. (1983).

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Table 1. Treatment evaluated

Treatment No.	Plant species	Plant part	Concentration
1	*Tagetes* sp. (Marigold)	Flowers	10/100 (w/w)
2	*Melia azedarach* L. (Persian lilac)	Leaves	10/100 (w/w)
3	"	Dry seed	10/100 (w/w)
4	*Schinus molle* L. (Pepper tree)	Leaves	10/100 (w/w)
5	"	Green seed	10/100 (w/w)
6	*Azadirachta indica* A. Juss. (Neem)	Leaves	10/100 (w/w)
7	"	Kernels	10/100 (w/w)
8	*Lantana* sp.	Green seed	10/100 (w/w)
9	(Pirimiphos-methyl)	(Control)	4 (ppm)
10	(Untreated)	(Control)	-

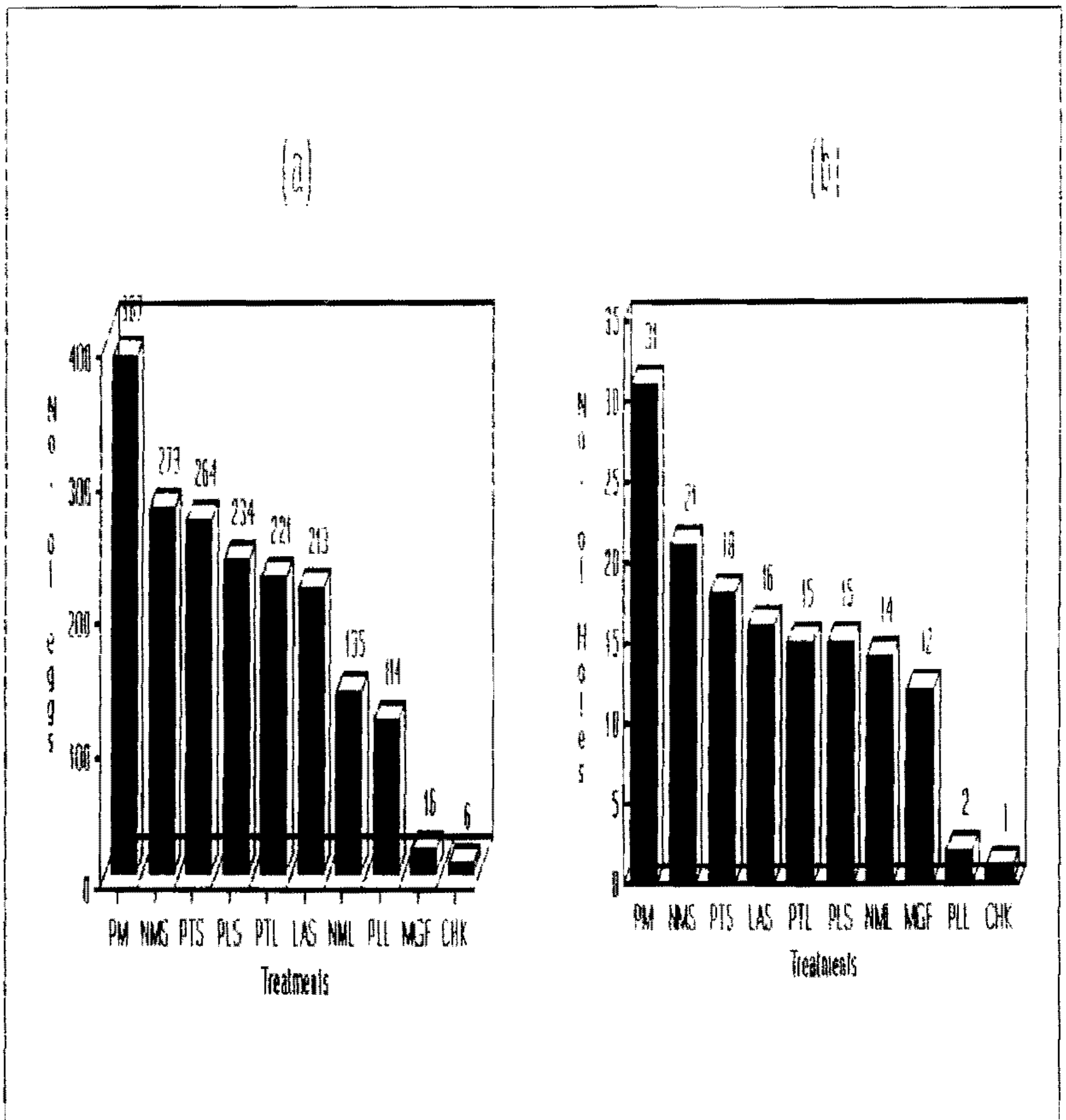

Figure 1. Effect of botanicals on number of eggs (a) and percent damaged seeds (b) on bean. PM= Pirimiphos methyl; NM= Neem; PT= Pepper tree; PL= Persian lilac; LA= Lantana; MG= Marigold; CHK= Check; F= Flower; L= Leaf; S= Seed.

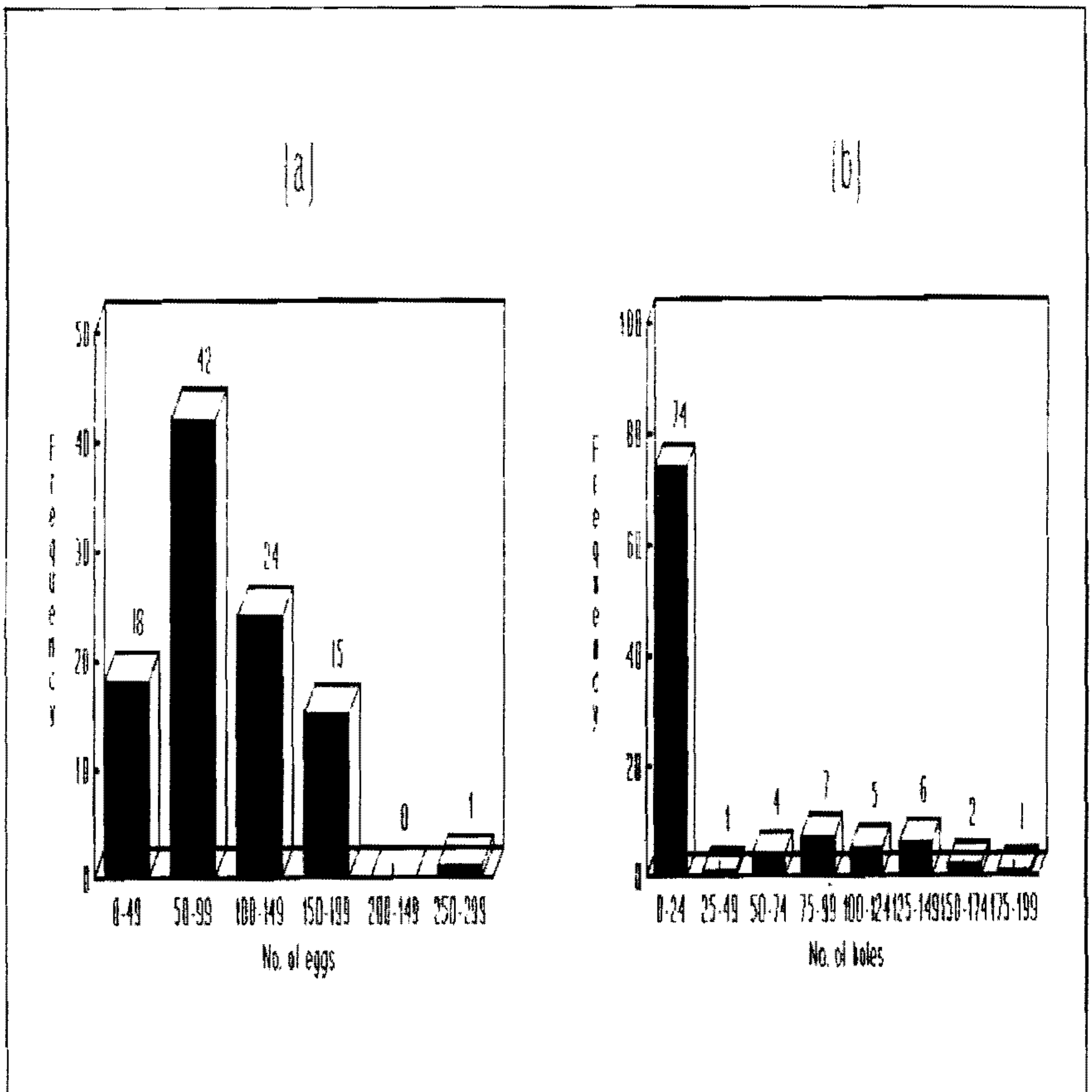

Figure 2. Frequency distribution of the number of eggs laid by female (a) and number of holes produced by emerging adult (b) bruchids on hundred accessions of bean.

HIGHLIGHTS OF BRUCHID RESEARCH IN THE GREAT LAKES REGION

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ABSTRACT

This paper reviews recent work conducted in Burundi and Rwanda, where losses to stored beans attributable to bruchids are commonly about 30%. At elevations of 900-1500 masl, Zabrotes subfasciatus is prevalent whereas, at higher altitudes Acanthoscelides obtectus predominates. Research has focussed both in socio-economic aspects, particularly traditional methods of storage in rural areas, and on measures of bruchid control. Surveys revealed that traditional methods of storage varied widely, and there were large differences also in the facilities used and in the quantities of bean seed stored. The use of pirimiphos-methyl, fenitrothion or fine-texture inert materials including laterite was found protective against bruchids, especially for storage periods not exceeding 74 days and when high humidity was avoided. Various "botanicals" have been tested, with up to 60% improvement over the control. Iboza (=Tetradenia) riparia was found the most effective insecticidal plant, even at a dose of 0.5% at which it provided six month's protection. Essential oils from Ocimum spp. were shown to have insecticidal properties, and Chenopodium spp. were found bruchid repellent. The bean cultivar Ubusobera and a yellow-seeded mixture showed some low level resistance against bruchids.

INTRODUCTION

For the communities of the Great Lakes Region (CEPGL), beans play an important role in human nutrition and provide up to 50 % of the total protein consumed in Burundi and Rwanda (Allen, 1987). In Rwanda, they are a source of income for farmers in the regions of Bugesera and Bugoyi; in Burundi, Moso, Bugesera and Bweru beans are the main cash crop. In other regions, most farming systems include beans even when agronomic conditions are sometimes marginal. Consequently, improvement programmes have put a lot of effort in the development of this crop. In recent years, particular emphasis has been put on the production of climbing beans which may

increase bean productivity and production. However, production is subject to qualitative and quantitative losses in storage. Organisms responsible for these losses essentially include stored product pests. Storage is unavoidable for various reasons, including the discontinuity of cropping seasons, the inability to consume all the harvest at once, social constraints, and market pricing in periods of abundance. It was therefore imperative to design strategies that could help reduce losses of this commodity, taking into account peasant realities. Several research projects were conducted in Burundi as well as in Rwanda to solve these problems. These research activities focussed on the socio-economy, the control measures against stored product insects, and extension work.
The research objectives on bean conservation focussed on the following areas:

(i) Socio-economic research, to investigate the different traditional methods of bean storage in rural areas.

(ii) Study of the control measures against pests of stored beans.

Socio-ecomomic research : traditional methods of storage

The aims of the socio-economic work in Rwanda and Burundi were to assess the traditional methods of conservation; to study variations in time and space of socio-economic parameters of stored commodities; and to study the socio-economic impact of improved methods of conservation and that of chemical control in rural area. The assessment of traditional storage techniques revealed different types of drying, different forms of conservation and locations in relation to the house. The different ways in which commodities are dried did not vary. Among the most common ones, one could mention: drying on the ground (43 %); drying above ground (49 %); storage in pods; and storing as grain was the most common.

Contrasting with the methods of drying and forms under which beans were stored, storage facilities also varied. Types commonly used were: pots; baskets weaved with reed and smeared with cow-dung; pile granaries; calabashes; and metallic drums (Autrique & Merten, 1977; Durnez, 1987; OPROVIA, 1988). We must mention that, with the exception of pots, the content of these structures varied. Many foreign items, which certainly contributed to the abundance of pests, could easily be found in these structures. Special attention must be drawn to Rwanda where cooperatives and OPROVIA had improved storage facilities (silos). These structures were well sealed and their contents were therefore well protected against insects (OPROVIA, 1988). Storage facilities mentioned above were either found in the house or outside the house. Granaries found outside the house were affected by the ground of the house or its fence. In most cases, it was noted that granaries were placed inside the house, in a room kept for that purpose, or in the kitchen on some platforms fixed above the fire.

The second socio-economic parameter of great importance which was studied by various groups was the variation of the stocks. The set-up of improved storage facilities was only possible when accurate information about traditional methods of conservation was obtained, as well as the evolution in time and space of stored commodities. In Burundi, the mean quantity of food in stock in 5 sites in kg/family/15 days was: 18 at Kabezi (IMBO); 32 at Giheta (KIRIMIRO); 63 at Bukirasazi (KIRIMIRO); 9 at Bukeye (MUGAMBA) and 3 at Mwaro (MUGAMBA). In Rwanda, investigations revealed that 2 months after the June harvest, the mean quantity of beans stored in Gatovu hill was 83 kg, while the harvest per family was 190 kg (Durnez, 1987). Generally, urban centres and major roads with heavy traffic influenced the quantity of commodities stored. The closer the sites were from these centres of influence, the lesser storage was observed.

Stored beans are attacked by several insect pests, the most important of which are: *Acanthoscelides obtectus* Say and *Zabrotes subfasciatus* Boheman. These insects are known by farmers to cause post-harvest losses. Farmers in Burundi and Rwanda have developed several control measures to fight bruchids. Some of these measures have no significant effect on the pests, however, when properly applied, others have good impact on the pest population. Work conducted in rural areas in Burundi and Rwanda showed that the following products were used: molar of a cow, tuber of "colocase", and "pili pili" (products presumably prepared from *Colocasia esculenta* and *Capsicum* sp., respectively. Ed). These products were ineffective; these practices were purely based on ancestry and customary beliefs. Similarly, fruit of *Stychnos potatorum* (which has strichnine as active ingredient), red soil, white soil, ashes, green leaves of tobacco (active ingredient is nicotine) and cow urine were believed to have insecticidal properties. Despite all care taken by farmers, work done in Rwanda indicated 4 % water loss against 1 % in the cooperatives warehouses and none in OPROVIA. These data showed that, in order to reduce these losses, there was a need to search for insecticidal products that will take into consideration the biology and behaviour of insects. It seemed that the use of phytosanitary products in rural areas was successfully introduced, but with some shortcomings, including a lack of insecticides, and lack of intensified chemical control. In fact, farmers smuggled phytosanitary products to protect their harvest in stores, especially beans. But they were not aware of the dangers of these actions. Insects are by far the major pest of stored beans, although some fungi are responsible for qualitative losses.

Control measures against pests of stored beans

In Burundi, work done by the Faculty of Agronomy was essentially oriented towards the use of insecticidal products, while FAO and UNICEF directed their effort at the improvement of methods of conservation (granaries, driers). Results of work done on the role of insecticides and inert products concluded that, firstly, high humidity of beans favoured attacks by insect pests and greatly reduced the efficacy of insecticides. Pyrimiphos-methyl (actellic) and fenitrothion were found suitable for bean protection against *A. obtectus* (Table 1). Inert products of fine texture, when properly dried, ensured bean protection against bruchids (Table 2). Some of these products were as good insecticides as those commonly in use. For example, fine granules of laterite at a dose of 1 % were as effective as fenitrothion for a storage period not exceeding 74 days. Two properties were responsible for results obtained with inert products, these were: their eroding property and their hygroscopic nature. For example, the low protection level of bean by kaolin was due to the absence of an eroding property, and a good hygroscopic ability. In contrast, laterite could be having a good potential for good protection due to its eroding ability, good hygroscopic ability and some toxicity due to iron and aluminum. Quartz had an excellent eroding ability but did not have ability to retain water. It could protect bean only at low levels of infestations. Laterite used as substrate for actellic improved the persistence of this insecticide. Furthermore, laterite seemed to favour germination of beans.

These results showed that inert products were as effective as chemical insecticides. They also have more advantages when compared to chemical insecticides. For example, laterite is found in abundance. It is cheap and non polluting. However, the use of these inert materials showed some disadvantages: for example, it was difficult to separate beans from the inert products powder. Winnowing which was the only procedure used for removing foreign objects from the grains was ineffective. Washing the beans with water is the only satisfactory alternative. However, the scarcity of water in rural areas is still a problem, even though effort for supplying water had been made. Therefore, good sanitation of granaries which has been advocated might be threatened.

Parallel to research on insecticidal products against bruchids, work on the improvement of storage processes was conducted and the following conclusions were drawn (BIANQUIS): (1) "Autobus" driers dried faster and better than traditional driers. (2) The various types of materials (bamboo, mats, grills) which made up the bottom of the platform above the fire on which commodities are placed for drying did not seem to significantly affect the speed and quality of drying. (3) Granaries must be clean and properly closed to achieve good storage.

In Rwanda, research conducted on bean conservation focussed on the following aspects: (a) use of products of plants origin; and (b) study of the differential resistance of the cultivated varieties of beans.

Several studies (Demaire, 1972, Kayitare and Gatarasi, 1973; Munyemana, 1986; Sindibona, 1988; Kayitare, and OPROVIA, 1988; Nizeyimana, 1991), indicated that:

(i) dried plant material gave a powder which was effective in reducing oviposition, hatchability, and increased larval mortality.

(ii) after six months of storage *Iboza riparia* remained the most effective insecticidal plant when compared to the other plants (*Capsicum frutescens, Ocimum* and *Chenopodium* spp.) (Table 3).

(iii) the lowest doses in weight needed for 6 months' protection of beans in storage were 0.5 % for *Iboza*, 1.0 % for *Capsicum*, 2.0 % for *Ocimum* and more than 2.0 % for *Chenopodium*.

(iv) essential oils of *Ocimum canum* had insecticidal properties. They inhibited fecundity, egg production in the ovaries of *A. obtectus*. In contrast, essential oils of *C. procerum* had no significant effect on these parameters.

(v) leaves and fresh flowers of *C. procerum* repelled bruchids. However, repellency was higher within the first 24 hours and leaves repelled more than the flowers.

(vi) resistant varieties of beans to bruchids were available but the level of resistance was so low that this genetic parameter alone could not be used in insect control.

Results of these studies can be efficient only if storage procedures are improved so as to increase sanitation, proper sealing, air tightness and proper ventilation of stores.

Extension work

The role of extension work is to adapt both theoretical and experimenatl knowledge to real conditions in a way that reduces efficacy as little as possible. For different reasons, including the lack of funds, low receptivity and illiteracy, extension work has had a restricted forum. In effect, the farmer is sometimes skeptical about new changes. It takes some time to influence him, because he is conditioned by his customs and traditional rites still rooted in him. Basic changes have therefore very little chance to be accepted and incorporated as daily practices. Extension work, therefore exploited the trilogy : good drying, use of insecticides and use of improved granaries. In affected areas, training target populations and setting-up appropriate storage structures led to the reduction of post-harvest losses. However, a large portion of the population did not adopt these techniques, either due to the lack of products or unawareness of the improved techniques of conservation.

FUTURE PLANS

The importance of bean production, population dependence on this crop, information already gathered about bean storage and the will to improve conditions and methods of storage are factors that contributed to the formulation of future activities. In

Burundi, future plans are summarized in the following topics:

(i) Follow-up studies on insecticidal inert products, particularly the dose, and size of granules of these products, in order to improve their influence and efficacy under normal conditions.

(ii) Elimination of protective media through washing and their effect on sanitation of the granary.

(iii) Improvement and dissemination of information about modern storage procedures.

In Rwanda, future activities on beans conservation is focussed on the following:

(i) Study of reception method, drying processes, sanitation and storage of beans in big storage centres.

(ii) Study of underground storage of beans

(iii) Study of major parameters associated with long term storage (3-4 years) of cultivated varieties of beans.

(iv) Identification of fungi and analysis of mycotoxin

(v) Study of botanical insecticides and possible insect resistance to these products.

CONCLUSIONS

Conservation of beans in Rwanda and Burundi is a topic that had generated a lot of enthusiasm in several research institutions. Research groups in both countries were primarily interested in improving methods of bean storage in order to minimize quantitative and qualitative losses of this crop which is so important to the population of both countries. With the exception of socio-economic aspects, their main research objectives were different but complementary. For instance, research institutions in Burundi were interested in the insecticidal properties of inert products while those in Rwanda worked mainly on insecticides from plants and on resistant varieties of beans. Applicable findings were obtained. Extension services with the support of these research institutions were able to disseminate some of this information. For example the use of actellic (Pirimiphos-methyl) in Burundi; and techniques and modes of bean storage in Rwanda. These same research institutions have planned to continue their work on specific aspects, including the dosage, size of granules of inert products to improve their efficacy; elimination of protective media; methods of drying; sanitation methods; handling of beans; underground storage; identification of fungi and mycotoxin.

Finally, for a better regional integration in this work, close professional contact between research scientists engaged in the work should be made. This will facilitate exchange of information and results and save both human and financial resources. In order to achieve that, sharing out the work seems to be the best solution. For example, Burundi could continue and strengthen its research on inert products, while Rwanda may concentrate on the study of the effect of essential oils and insecticides from plants.

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Table 1: Probit transformation of Bruchid mortality.

Insecticides time (days)	Fenitrothion		Actellic		Malathion		Nexion	
	y	Y	y	Y	y	Y	y	Y
4	9.00	7.28	9.20	8.18	8.40	6.30	6.10	6.09
13	8.15	6.92	8.45	7.73	7.65	6.12	5.80	5.82
17	7.80	6.76	8.15	7.53	7.35	6.04	5.70	5.70
23	7.28	6.52	7.67	7.23	6.88	5.98	5.60	5.52
30	6.65	6.24	7.10	6.88	6.30	5.92	5.30	5.31
34	6.30	6.04	6.80	6.68	6.00	5.70	5.20	5.19
39	5.85	5.88	6.40	6.43	5.60	5.60	5.10	5.04
43	5.50	5.72	6.10	6.23	5.30	5.52	5.00	4.92
47	5.15	5.56	5.80	6.03	5.00	5.44	4.80	4.80

y = expected values
Y = calculated values

note: Probit transformation of 100 % was taken as 99.99% (as 100% does not exist in Fisher and Yate's tables)

Table 2: Percent beans attacked by bruchids 74 days after storage.(± standard deviation)

Product	Grain size / Dose (%)	1	2	3
Kaolin	5	23.1 ± 8.27	27.70 ± 1.24	62.5 ± 3.95
	1	30.7 ± 6.97	34.55 ± 2.46	73.05 ±12.91
	0.1	60.1 ± 5.14	41.28 ± 4.08	81.7 ±11.85
Quartz	5	27.76 ± 8.58	21.90 ± 9.35	24.55 ±0.79
	1	25.61 ± 4.21	28.48 ± 8.94	27.73 ±7.62
	0.1	42.90 ± 6.91	64.21 ± 6.04	77.78 ± 8.12
Laterite	5	6.45 ± 5.51	5.38 ± 0.42	10.00 ± 3.31
	1	9.58 ± 5.35	11.02 ±10.18	7.10 ± 3.98
	0.1	43.96 ± 7.71	24.85 ± 5.48	14.68 ± 5.48
Fenitrothion	10 ppm.	3.14 ± 2.55		
Control		66.46 ± 2.0		

1 = < 300 > 250
2 = < 180 > 125
3 = < 75 > 45
Source: Nindereye (1979).

Table 3: Losses after 6 months

Plant	% losses
Iboza riparia (Hochst) N.E. Br.	9.3
Chenopodium schraderanum Schult.	20.7
Capsicum frutescens L.	14.5
Ocimum kilimandscharicum Guerke	20.7
Control	24.7

source: Munyemana (1986)

RECENT ADVANCES IN THE DEVELOPMENT OF STRATEGIES FOR MANAGING BEAN STEM MAGGOT (*Ophyomyia* spp.) IN BEAN

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ABSTRACT

This paper highlights the recent advances in research and other developments in bean stem maggot (BSM) control by the BSM collaborative research network. Studies in BSM ecology and species distribution indicate that O. spencerella and O. phaseoli are the predominant species throughout Africa. O. spencerella predominates in high to medium altitude (cool) environments but does not occur outside the continent. O. phaseoli is more widespread especially in lowland (warm) environments across Africa and beyond. Species determination was established through a workshop in collaboration with taxonomists from the International Institute of Entomoloiy (IIE). Puparial characteristics were adopted as reliable indicators of BSM species. This is supported by aedeagal and isoenzyme analyses.

Various 'hot spots' for individual species have been identified and are used for screening. By exploiting knowledge of BSM population dynamics and cycles of reversal in species dominance, it is possible to evaluate germplasm and other materials in a single location against populations that are predominantly one species or the other.

'Hot spots' with known species composition have been used to screen germplasm and breeding lines for resistance to BSM. Accessions such as ZPv 292, BAT 1373, G 5773 and Ikinimba, have shown consistent resistance, and have been used in further crosses to incorporate resistance in agronomically acceptable backgrounds. Many such crosses are currently under evaluation in several locations within the BSM research network.

Other control measures that are being explored include cultural methods, amongst which mulching with straw seems to offer promise. This may be exploited in combination with moderate resistance and seed dressing with chemicals of low mammalian toxicity to reduce damage by bean stem maggot.

INFLUENCE OF PLANTING DATE ON THE OCCURRENCE OF THE BEANFLY (DIPTERA : AGROMYZIDAE) ON BEANS

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ABSTRACT

The results of this study showed that greatest population densities of the bean stem maggot, or beanfly, occurred 4-6 weeks after emergence of Phaseolus vulgaris at two sites in Swaziland. The study also revealed that the densest populations of Ophiomyia developed between January and February. Early planting, in November, allowed the bean crop to escape from severe attack. Proper control strategies should be launched just before the 4th week after crop emergence. Both O. phaseoli and O. spencerella were identified during this study : O. phaseoli appeared to be the more widespread and abundant species.

INTRODUCTION

Beans (*Phaseolus vulgaris*) form an important source of supplementary protein to the cereal-based diet of the Swazi people. Beans are a cash crop, but are grown only on about twenty five percent of the arable land. Most bean production is for subsistence consumption with small amounts being marketed. Increased bean production can only be achieved if good agronomic practices are combined with good pest management procedures. Like most other field crops, it is subject to attack by a variety of insect pests during its growing stages.

The beanfly (*Ophiomyia phaseoli* and/or *O. spencerella*) is one of the insect pests that severely damage the young crop. The eggs which are laid on the leaves hatch into maggots which bore inside the veins of the leaves and work their way down the stem, devouring the tissues of the stem causing wilting and yellowing of leaves, then death of the plant. At the base of the stem, the maggot pupates for a few days and emerges as an adult fly. They soon mate and begin to lay eggs to start the cycle again. In older plants (5-8 weeks), the damage is not so severe but lodging occurs. There are two or three species of beanfly which occur in Swaziland but it has not yet been established which species prevails and causes most damage. Also information on the abundance of this pest in a given planting season is wanting.

Consequently, this study was undertaken to investigate the density of populations of stem maggot and their damage to beans, and identify the most abundant species occurring in the region.

MATERIALS AND METHODS

Planting date effects were examined by monitoring population levels of stem maggot (*Ophiomyia* spp.) attacking two bean cultivars planted on four dates in 1991/92. The dates were spaced about one month apart (7 Nov, 5 Dec, 4 Jan and 3 Feb) with the latter two dates corresponding with the probable planting date of beans in Swaziland. The test was conducted at Malkerns Research Station, on loamy clay soil, and Nhlangano Experimental Station, on sandy loam soil. The other two sites, Mangcongco and Lowveld Experiment Station did not perform well and those trials were discontinued.

Plots consisted of two rows by 6.0m long, with a row spacing of 60cm and 9cm between plants. The experimental design was a randomized complete block (RCB) split-plot arrangement with four replications. Whole plots were the four planting dates and sub-plots were two bean cultivars (Seminole and Bonus) which were easily available. Basal fertilizer (2:3:2)22 was applied following the recommendations in the region.

Sub-plots were systematically sampled at 4 weeks, 6 weeks and 8 weeks after plant emergence for natural infestation of stem maggot. Ten plants per plot were visually inspected for damage characteristic of Dipteran maggots. Plants were dissected and pupae collected and cultured in the laboratory for species identification. Pupae were counted and plants destroyed.

Resultant pest population densities were analysed by ANOVA with planting dates and bean cultivars serving as the main factors in the analysis. Treatment means were separated by Duncan's Multiple Range Test.

RESULTS AND DISCUSSIONS

Natural infestation of beanfly was affected significantly by planting date of the bean crop. The first and second time of planting (7 Nov & 5 Dec) were least affected by the stem maggot, and higher yields were recorded relative to third and fourth plantings (4 Jan & 3 Feb) which had a severe attack of the stem maggot (Table 1). Planting date effects were highly significant. A significant difference was also observed in the interaction of planting date and cultivars ($P = 0.003$). Stem maggot populations were densest at both locations (Malkerns and Nhlangano) in samples taken in the 4th week (Fig. 1).

Ophiomyia phaseoli was more abundant than *Ophiomyia spencerella*.

O. phaseoli was found at all altitudes, yet *O. spencerella* appeared better adapted to higher altitudes. *Ophiomyia phaseoli* is easily recognized by its brown pupae and *O. spencerella* has black pupae. Seminole proved to be superior to Bonus in terms of yield at both locations. Differences in plant damage between planting dates may possibly have been the result of different stem maggot population densities.

CONCLUSION

The results of the study showed that higher population densities of the stem maggot occurred from the 4th to 6th weeks after plant emergence. The study also revealed that high population densities develop between January and February (3rd & 4th plantings). Early planting, especially in November, allows the bean crop to escape heavy attack by stem maggots. The study also revealed that proper control strategies aimed at controlling the beanfly should be launched just before the 4th week after emergence.

Table 1. Effect of time of planting on beanfly infestation and seed yield in two bean cultivars.

Planting date	Infestation (%)	Mean Yield (kg/ha)
7 Nov	0.01 c	484.3 a
5 Dec	1.51 b	271.5 b
4 Jan	5.00 a	171.6 bc
3 Feb	5.19 a	35.8 c

Means in the same column with the same letter are not significantly different at 5% (DMRT)

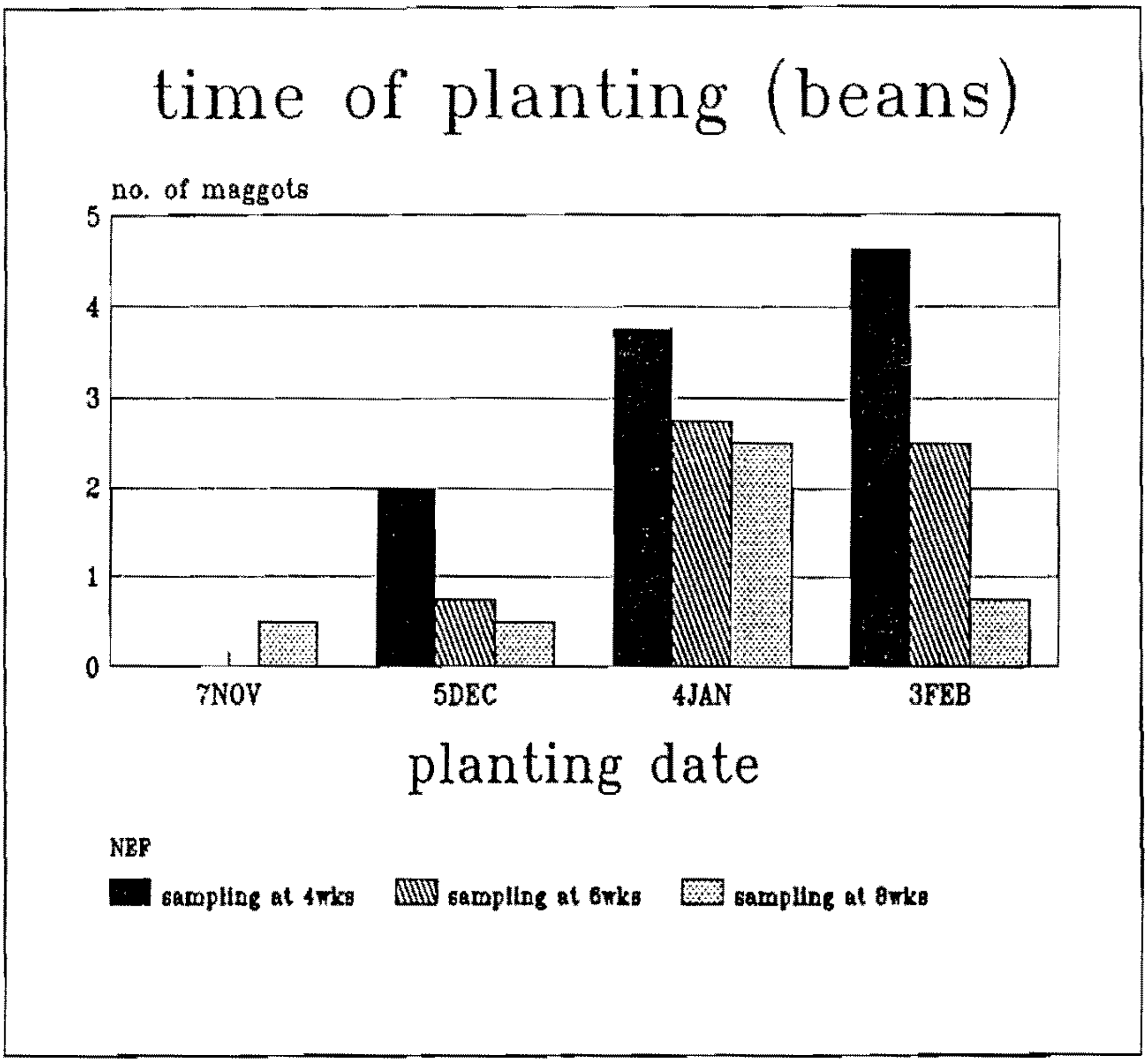

Figure 1. Effect of time of planting on populations of the bean stem maggot in two cultivars of bean at Malkerns and Nhlangano, Swaziland.

EVALUATION OF PROSPECTS FOR INTEGRATED CONTROL OF BEAN STEM MAGGOT (Ophiomyia spp.) AT LICHINGA, MOZAMBIQUE

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ABSTRACT

Prospects for intergrated control of bean stem maggot on the Niassa plateau in northern Mozambique are good. Evaluation of the phenology of the bean stem maggot in four seasons has shown that the predominant species in Ophiomyia spencerella and that infestation is low at the begining of each planting season and increases with delay in sowing. Timely planting (early December and early March) reduces infestation by bean stem maggot. A programme to select resistant or tolerant varieties found some promising local and exotic varieties (the best being Ikinimba from the beanfly nursery) but also highlighted an interaction between bean stem maggot and root rots. Two insecticide seed dressings, endosulfan and diazinon, both available locally, have been shown to be highly effective in controlling bean stem maggot. Screening natural products, available locally, against bean stem maggot, showed some promising products including tobacco and Tephrosia vogelii as seed dressings and chilli pepper (piri-piri) as a foliar spray. Using a combination of these technologies in such a way as to preserve the natural enemies of the pest, it should be possible to control bean stem maggot in the local farming system.

INTRODUCTION

Bean Stem Maggots (*Ophiomyia* spp.) have been identified as a constraint to production of common beans on the plateau areas of Niassa, around Lichinga where beans are predominantly grown by small farmers. At the Lichinga Research Station we have been developing an integrated approach to controlling this pest in a farming system that uses minimum inputs. The approach has been to investigate the phenology of the pest, define the level of damage done and suggest and evaluate practical control responses.

PHENOLOGY OF BEAN STEM MAGGOT IN NIASSA

The main growing season is between December and June with two planting seasons, one in December (in a maize intercrop) and one in March (relay crop in maize). Rainfall is unimodal, with an average of 1,140 mm per annum, received mostly between November and April. Trials have been conducted in four growing seasons to monitor infestation of bean stem maggot to three varieties of beans. Each trial was a latin square design sown every month from mid-December to mid-April with two local cultivars (Encarnado and Manteiga) and one exotic (A 417). Encarnado was grown both with and without insecticide seed treatment. At the same time, the species of bean stem maggot present were identified by pupal colour and the emergence of adult flies and parasites from collected pupae observed.

Over the four seasons the predominant species has been *Ophiomyia spencerella*, usually representing more than 90% of the pupae collected at any sowing date. Infestation of beans, evaluated by counting the number of larvae and pupae in 10 plants chosen at random per plot, varied within the season but maintained a consistent pattern between seasons (Figure 1). Infestation is low early in the first planting season (early December) but rises with delay in planting, peaking in January or February, before declining in March. In some years infestation increases towards the end of the second planting season (April). The yield of beans mirrors the change in infestation by bean stem maggot, but is not necessarily caused by the level of infestation because decreases in yield are often in plots where bean stem maggot has been controlled. Complicating factors include the incidence of stem and root rots and their interaction with bean stem maggot.

Percentage emergence of adult flies from collected pupae varies during the season, being lower in mid-season, as does percentage parasitism which is highest in mid-season. Total parasitism varies between 0 and 40%, depending on date of collection of pupae. Table 1 shows the results for the season 91/92 both for date of sowing and species of bean stem maggot. The data represent a typical season and show *O. spencerella* is parasitised mainly by *Eucloidea impartus*, but also by *Opius melanagromyzae*, while *O. phaseoli* is mainly parasitised by *O. melanagromyzae*, and at a higher level.

At Lichinga, a third bean crop is planted in the dry season (August-November) using residual ground water which is the likely overwintering site for beanfly.

CONTROL OF BEAN STEM MAGGOT

While parasites may help to regulate the population of bean stem maggot, they do not provide control of this pest and efforts at Lichinga have concentrated on investigating cultural and chemical control.

Cultural control

Time of sowing

From the results of the study of infestation within the main crop season, there are two optimum times for sowing. The first is as soon as possible after the rains have started in mid-November, the main constraint being the need to sow the maize crop and let it get established before sowing the beans in intercrop. The second is after the decline of the beanfly population in March, the main constraint being to avoid the lack of moisture at the end of the crop cycle.

Resistant varieties

A second approach has been the selection of resistant varieties. One trial has been carried out with the aim of evaluating the 20 or so local cultivars of beans for tolerance/resistance to bean stem maggot. Two small seed cultivars, Encarnado Fino and Kaela (R), have shown low levels of infestation.

A second trial was initiated to confirm resistance in 4 varieties selected from the CIAT BNFLY nursery and from observations in other trials. The varieties were Ikinimba, ZPV 292, ICA Pijao and A 417 and they were compared to the two local cultivars Encarnado and Manteiga. The varieties were evaluated in a split plot design which included insecticide treatment on main plots and varieties on sub-plots, and advantage was taken of the design to assess the effect of root rots and any possible interaction with bean stem maggot. Infestation by bean stem maggot was assessed at 20,30 and 45 days after emergence (dae) by counting the number of dead plants and then assigning them to three categories based on cause of death; bean stem maggot, root rot or bean stem maggot and root rot.

From an overall assessment of the results (Table 2), it seems that insecticide considerably increased yield (from 99 to 383 kg/ha). There was no significant difference between the varieties in terms of mortality due to bean stem maggot, although the two local cultivars showed twice the percentage mortality of the other varieties. Less bean stem maggot was collected from the varieties Ikinimba, A 417 and ICA Pijao (Table 3). The numbers of bean stem maggot per dead plant were highest for the varieties Encarnado and ZPV 292. Insecticide seed treatment was highly effective in controlling the bean stem maggot, reducing infestation to zero.

Further evaluation of the results showed an interaction between bean stem maggot and root rots that deserves further study (Table 4). The percentage mortality due to root rots is similar with or without insecticide treatment (in 23%). With insecticide, the percentage mortality due to bean stem maggot was zero in comparison with 15% without insecticide treatment. However without insecticide a further 27% of plants died due to bean stem maggot and root rots in combination. In practice we observed an increase in percentage mortality from 30% with insecticide, and therefore without bean stem maggot, to 76% without insecticide, and therefore with bean stem maggot. This represents an increase over and above that expected from considering the percentage plant mortality with root rot and bean stem maggot acting independently (about 23 + 15 = 38%).

From these results it would seem important to select varieties resistant to both root rots and bean stem maggot. From the point of view of pest management it seems possible to select resistant varieties to help combat bean stem maggot.

Chemical control

The most promising method of chemical control is insecticidal seed dressing. As well as evaluating insecticides we have pursued the use of natural plant products to control bean stem maggot.

Insecticidal seed dressings

The use of insecticide seed dressings has proved successful with two locally available insecticides. Both Basudine (diazinon 60% ec at 1,7 ml/kg seed) and Endossulfao (endosulfan 50% ec at 7,5 ml/kg seed) have been shown to successfully control bean stem maggot. These two insecticides are currently recommended when available and especially where beans are planted late.

Natural plant products

The use of natural plant products for the control of crop pests has some advantages to the small farmer over synthetic insecticides, including the fact they are normally cheaper and not normally highly toxic to people, animals or the environment. The disadvantages of these products are that they take time to prepare and are rarely as efficient as synthetic insecticides.

A trial was initiated this season to investigate the possibilities of using tobacco (*Nicotiana tabacum*), garlic (*Allium sativum*), chilli peppers or piri-piri (*Capsicum frutescens*), mata-peixe (*Tephrosia vogelii*) and basil (*Ocimum basilicum*) which are widely available locally. The products were prepared by macerating the plant material and soaking them in a soap/water base following recipes given by Gaby Stoll (1986). All were evaluated as both a seed treatment and foliar treatment. Only the insecticide control showed less infestation by bean stem maggot than soap and water although piri-piri (foliar treatment), mata-peixe (seed treatment) and tobacco (seed treatment) showed promise (Table 5). We will continue to evaluate these products in the next season.

SUMMARY

In summary, the prospects for a range of recommendations and technologies for effective control of bean stem maggot on the Niassa plateau are promising. By a combination of manipulation of sowing date, selection of resistant varieties and the use of chemical seed dressings, it should be possible to significantly reduce the incidence of this pest. However, the work on resistant varieties shows that care needs to be taken not to overlook other factors such as root rots. The economic value of any yield improvements is also an area of possible future study.

ACKNOWLEDGEMENTS

Acknowledgements are due to two technicians, Carlindo Tocoro and Sancho Cumbi, who both played a significant role in the execution of this work.

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Table 1. Percentage emergence of pupae and percentage parasitism with a) date of sowing and b) species of bean stem maggot, 91/92 season.

Date of sowing	Total pupae	Percentage(%) pupae with Beanfly	*E.imp*.*	*O.mel*.*	Other p.	total parasitism	total emer.
14 DEC	15	12.0	0.0	0.0	0.0	0.0	80.0
14 JAN	395	37.2	10.9	9.1	0.3	20.3	57.5
14 FEB	239	13.4	11.3	4.6	0.0	15.9	29.3
14 MAR	84	11.9	6.0	8.3	1.2	15.5	27.4
14 APR	665	22.7	4.1	1.8	2.1	8.0	30.7
Species							
O.spenc.	1345	25.0	7.4	3.6	1.1	12.1	49.2
O. phas.	53	24.5	1.9	24.5	1.9	28.3	52.8

* *Eucloidea impartus, Opius melanagromyzae*

Table 2. Summary of the results for the bean stem maggot resistance trial, 91/92 season.

Variety	Yield (kg/ha) (-) insecticide	(+)	Vigour (1-9)	Percentage (%) plants dead with Bean Stem Maggot	No.BSM per dead plant
Ikinimba	326 a	790 x	4.8 a	11.7 ns	1.91 a
ICA Pijao	108 b	773 x	7.2 b	10.9 ns	2.23 a
A 417	89 b	470 y	6.8 b	11.9 ns	2.52 a
ZPV 292	33 b	63 z	6.0 ab	12.1 ns	3.31 b
Encarnado	25 b	135 z	6.5 b	22.7 ns	4.31 c
Manteiga	10 b	153 z	7.3 b	23.2 ns	2.50 a
$\bar{X}$	99	383	6.4	15.4	2.80

means in the same column with the same letter not significantly different at 5% (DMRT)

ns : not significantly different by ANOVA.

Table 3. Numbers of bean stem maggot collected by variety and insecticide treatment. 91/92 season.

Variety	Insecticide -	Insecticide +	X	S.E	C.V.
Ikinimba	92.0 a	0.0	46.0		
A 417	114.3 a	0.0	57.2		
ICA Pijao	130.7 a	0.0	65.3	23.7	59.7%
Manteiga	174.3 ab	0.0	87.2		
ZPV 292	243.0 b	0.0	121.5		
Encarnado	413.0 c	0.0	206.5		
$\bar{X}$	194.5	0.0	97.3		
SE	30.9				
CV	55%				

Table 4. Percentage mortality with bean stem maggot and root rot with and without insecticide treatment, 91/92 season.

Insecticide	Percentage plant loss with : Root rot	BSM	Root rot + BSM	(Total)	Observed
-	22.45 a	15.41 a	27.07 a	(65.6)	75.9 a
+	23.85 a	0.00 b	0.00 b	(23.9)	30.1 b

Means with the same letter in a column not significantly different at 5%.

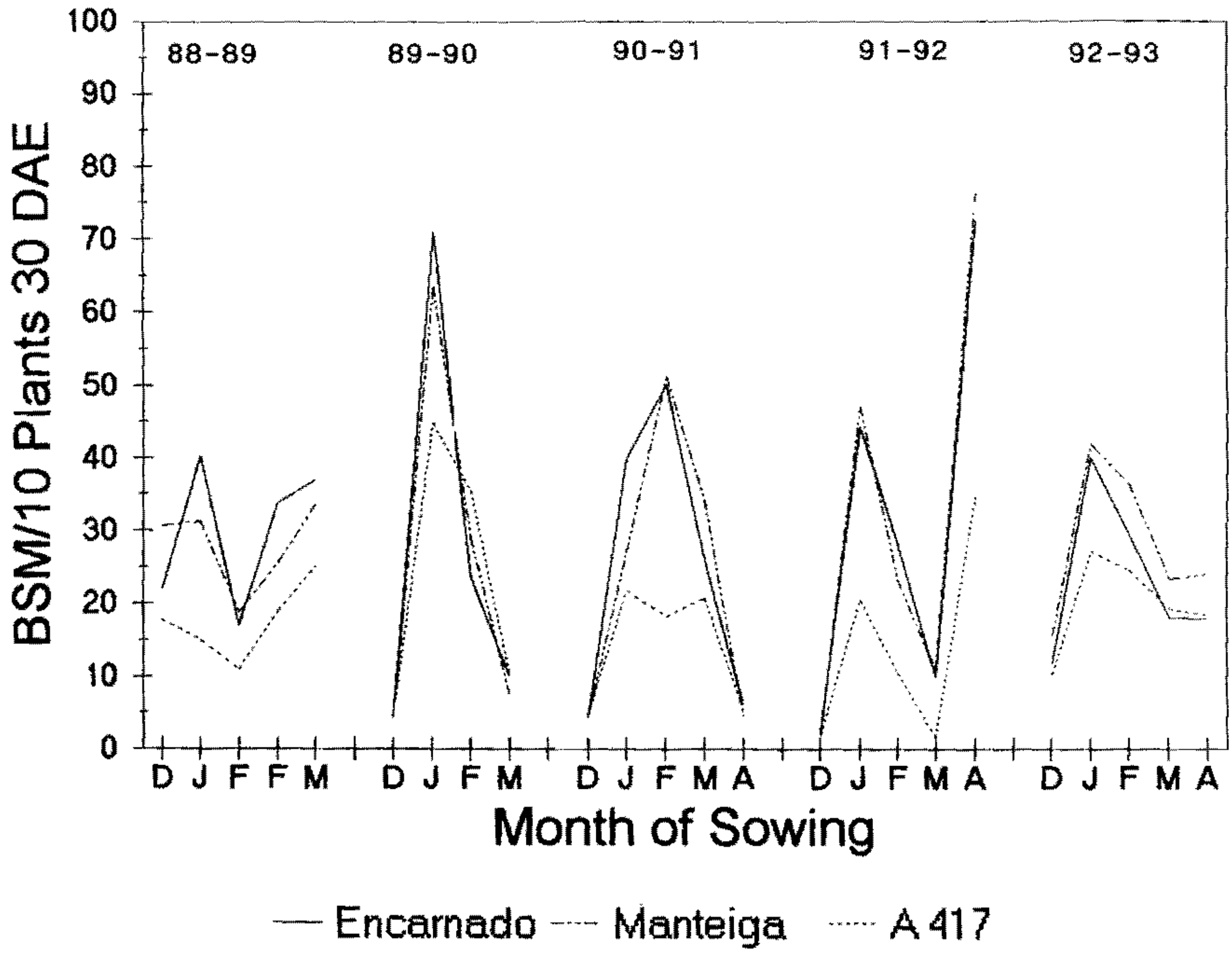
Table 5. Number of bean stem maggot per 10 plants 30 dae with product and manner of application, 91/92 season.

Product	Treatment to : Seed	Leaves	X	SE
Insecticide	0.0	0.0	0.0 a	
Piri-Piri	2.3	1.0	1.7 ab	
Mata-Peixe	1.7	2.7	2.2 bc	
Tobacco	2.0	3.7	2.8 bc	0.86 (0.24)
Basil	3.3	3.3	3.3 bc	
Soap + Water	2.7	5.0	3.8 bc	
Garlic	5.3	4.0	4.6 c	
$\bar{X}$	2.5	2.8	2.6 (1.6)	
SE	0.46 (0.12)		1.23 (0.34)	
CV			80.2 (35.6) %	

data transformed with $\sqrt{x + 0.5}$ for analysis, original means shown.

means with same letter not significantly different at 5% (DMRT)

Figure 1:



100
90
80
70
60
50
40
30
20
10
0
88-89
89-90
90-91
91-92
92-93
BSM/10 Plants 30 DAE
D J F F M D J F M D J F M A D J F M A D J F M A
Month of Sowing
Encarnado
Manteiga
A 417

DISCUSSION OF THE ENTOMOLOGY PAPERS IN THE CROP PROTECTION SESSION

Questions following **M.L. Pomela**'s paper brought out the following points :

(i) The effect of predators will need to be considered when assigning an economic threshold.

(ii) The cages will have an effect on the growth of the plants and this will have to be accounted for, or at least described, by comparing with un-caged plants. Control cages (plants with no insects) will have to be continued.

(iii) What is the movement of predators in relation to the spiny brown bug ? What are the predators' environmental limits ?

Discussion that followed the papers concerning bruchid research presented by **Giga and Chinwada, Silim Nahdy, Federe Negasi** and **Nahimana** was summarized by the Rapporteur as follows :

(i) RAZ lines contain the arcelin gene and are resistant to *Zabrotes* spp. There is some progress in identifying lines resistant to *Acanthoscelides* spp., but so far they are small-seeded types and the resistance has not been successfully transferred into more acceptable grain types.

(ii) There is a difference between infestation, weight loss, and economic loss as regards bruchids. An average of one hole per bean can result in a 50% reduction in market value, and 16% weight loss is equivalent to 100% infestation.

(iii) A number of comments were raised about bean storage conditions. Concern was expressed about using botanicals that have high mammalian toxicity. Tumbling the beans in their storage container every six hours was recognized as being effective, but generally impractical. The husks of rapoco (finger millet) act as a repellent rather than as a toxin and results from its use will vary depending on how tests are conducted. This implied that both 'choice' and 'no choice' tests need to be conducted. Due to the effectiveness of diatomaceous earth, it may be worthwhile exploring other soil sources that may have particles of similar size (eg. lateritic soils, clay, termite mounds). Vegetable oils can be effective against bruchids at a rate of 5 ml/kg of bean seed, but this may be of practical use only for researchers.

There may be some differences among sources of wood ash. Different trees may leave different residuals in the ash, but this is not very likely due to the high temperatures that eliminate the organic compounds. Dung ash was suggested as a possible treatment. Farmers report that the storage of beans in these various mixes reduces the marketability of the grain. Most of the storage methods would be used for seed for planting in the next season. A challenge was raised to test various storage methods on the quality of grain for consumption and marketability.

Papers on the bean stem maggot (BSM) by **Ampofo, Nsibande** and **Davies** stimulated discussion summarized as follows :

(i) In the Great Lakes Region, green manures and mulches have been found useful for controlling root rots. It may be useful to evaluate these mulches on BSM, in recognition of the fact that root rots, poor soil fertility and BSM often seem to be associated. When mortality is being evaluated, it is essential that the different causes of death be as accurately evaluated as possible.

(ii) Species composition (*O. spencerella* vs. *O. phaseoli*) appears to be related to temperature, with *O. spencerella* occurring more during cooler parts of the season.

(iii) Sampling for BSM should start two weeks after emergence, though this may be delayed during cool seasons. When monitoring populations, a substantial separation of plots is mandated when delayed plantings are spaced more than a month apart. This is to avoid creating an inoculum for the later plantings. It needs to be recognized that BSM populations go through natural cycles during the year, as a result of changes in the environment and in the level of parasites or predators. Light traps and 'sticky' tape can be used for monitoring populations, but they have deficiencies and counting dead plants is still the best method.

(iv) IPM needs to be developed for each area. Mozambique recommends early planting, whereas Ethiopia recommends late planting. There may be some use for research to determine ways for managing naturally occurring populations of predators.

(v) Prof. Teri related that I. Newton once commented that as beautiful and as special as a pebble on a beach can be, we still have an ocean of mystery in front of us !

A REVIEW OF THE SADC/CIAT APHID/BCMV SUB-PROJECT IN ZAMBIA AND TANZANIA

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ABSTRACT

The black bean aphid, Aphis fabae Scopoli, was observed in 25 out of 39 farmers' bean fields surveyed. Besides A.fabae, the alatae aphids of Toxoptera citricidus (Kirkaldy), Brevicoryne brassicae (L.) and Tetraneura nigriabdominalis (Sasaki) were occasionally found in northern province in a 1989 survey. Bean common mosaic virus was found in 45 out of 88 samples of farmers' bean seeds with north-western province recording the highest percent seed-borne BCMV. During 1989-92, a total of 15 aphid species were collected in yellow pan water traps. Myzus persicae (Sulzer) was by far the most abundant species recorded throughout the period. The next in abundance were Aphis craccivora Koch, A. gossypii Glover and A. spiraecola Patch, in descending order.

In a BCMV/aphid incidence trial, BCMV was greater in late planting than in an earlier one, presumably due to high aphid activity in the later planting. The seed yield in early planting averaged 1035 kg/ha, while under late planting it was only 317 kg/ha. In a bean/ maize intercropping trial, 2 rows of maize to 1 row of bean resulted in substantial reductions in BCMV incidence and aphid infestation. In an aphid/BCMV transmission study, A. craccivora, A. fabae and A. gossypii were capable of transmitting BCMV under screenhouse conditions. Percent success increased with increasing number of aphids per plant. In a survey on BCMV strains, two strains, NL3 and NL6, were identified prevalent in the two districts of eastern province. Limited work was done in Tanzania on aphid infestation in farmers' bean fields and aphid catches from the yellow pan water traps.

INTRODUCTION

Aphids are the most important vectors of plant viruses and can cause considerable yield loss in beans. The bean aphid. *Aphis fabae* Scopoli, is a major pest of common beans, *Phaseolus vulgaris* L., and other leguminous plants in the tropics and is reported as being a vector of more than 30 viruses (Hill, 1975). *A. fabae* plays an important role in the spread of bean common mosaic virus (BCMV), which affects beans in several areas of eastern (Kulkarni, 1972; Kaiser, 1976) and southern Africa (Kannaiyan et al., 1987). Several aphid vectors have been reported capable of transmitting BCMV (Zaumeyer and Thomas, 1957; Kennedy et al., 1962; Khaemba and Latigo, 1982; Mali, 1986; Mukhopadhyay and Chowdhury, 1986; Zettler and Wilkinson, 1966). Remaudiere and Autrique (1985) contributed to the understanding of the ecology of the African aphids. However, there is little information available in the exact species occurring in the bean ecosystem, their distribution, population dynamics and their status in relation to spread of BCMV.

In July 1989, the aphid/BCMV regional research sub-project was initiated with the following objectives : (1) to identifify the aphid species occurring in the bean enviroment in Zambia, Malawi and Tanzania, (ii) to understand the population dynamics of the aphids in relation to BCMV incidence, and (iii) to ascertain the aphid species that transmit BCMV and their relative efficiency of trasmission of the BCMV strain(s) occurring in the region. This paper reviews the progress of the bean aphid/BCMV sub-project during phase I (1989-1992).

Bean aphid/BCMV incidence in farmers' bean crop

A roving survey was carried out in eastern, central, Luapula and northern provinces of Zambia in 1989-91. Twenty-five out of 39 bean fields visited had infestation by aphids (Table 1). It was also found that *A. fabae* commonly occurred on beans. The alatae aphids of *Toxoptera citricidus* (Kirkaldy), *Brevicoryne brassicae* (L.) and *Tetraneura nigriabdominalis* (Sasaki) were occasionally found in northern province in 1989. The percentage of aphid infested plants was greater in the sparsely planted plants (3-5 plants per sq. metre) than in the dense (21-56 plants/sq. metre) ones. A survey carried out in 1991 in the high rainfall ecological zone had fewer bean plants infested by aphids compared with the 1989 results. In Tanzania, the aphid counts per plant at Uyole Agricultural Centre and Mitalula were high in June and August with an average of 37.4 and 50.9, respectively. In the 1991 survey, 18 out of 23 bean fields visited had BCMV. The mean number of BCMV infested plants was estimated to exceed 14,000/ha while the mean percent averaged 13.0 % (a range of 0 to 72%).

Extent of seed-borne BCMV in farmers' bean seeds

Seed infection is perhaps the most important means of spread of BCMV (Morales, 1989). Surveys were conducted in three provinces of Zambia during 1989-91 to estimate the prevalence of seed-borne BCMV in farmers' seeds. Farmers were chosen at random along motorable roads. A total of 88 samples of farmers' bean seeds were assessed for seed-borne BCMV during the two years. The results showed that 45 out of 88 samples of bean seeds collected had BCMV

(Table 2). The north-western province had the highest percent seeds with BCMV. In general, this indicated that the carryover of BCMV through seeds was substantial in all regions of Zambia surveyed.

Effects of relay intercropping on aphid infestation and BCMV incidence

During 1989-90, a trial was conducted at Msekera to study the effects of growing bean in association with maize on BCMV incidence and infestation. It consisted of four treatments arranged in a randomized complete block design with six replications. The spacing between ridges was 50 cm, maize (cv. MM 604) was planted at 20 cm within the row on January 9, 1990 whereas bean (cv. Misamfu Speckled Sugar) was planted three weeks later, at 10 cm intra-spacing. Each plot was composed of 11 ridges of 4m length. The recommended cultural practices were followed except that bean did not receive any insecticide after emergence. BCMV incidence was recorded in three rows of beans in each plot at intervals while the number of plants colonized by aphids was recorded weekly from 22 February to 21 March. BCMV incidence, as percent plants colonized by *A. fabae,* were least in 1 row bean to 2 rows of maize (Table 3), thus, the arrangement of 2 rows maize : 1 row bean seems to be least suitable for aphid dispersal and/or multiplication. Altieri et al., (1978) have shown that intercropping bean with maize was beneficial against the leafhopper, *Empoasca kraemeri* Gross and Moore, the beetle, *Diabrotica balteata* Leconte, and the caterpillar, *Spodoptera frugiperda* (J. E. Smith) because of interference with their colonization and the increase in populations of their natural enemies. Recently, Katunzi et al., (1987) confirmed that intercropping of bean with maize reduces the severity of BCMV and other diseases.

Aphid landing in yellow pan water trap

A yellow pan water trap (60x60x10cm) was installed at 70cm above soil level within the bean field at Msekera during 1989-92. The alatae aphids were collected thrice per week and preserved in 70% alcohol for identification. The water was changed whenever necessary. The trap collections commenced in January and ended at crop harvest in March/April each year. The results are shown in Table 4. A total of 15 aphid species were collected in the trap during 1989-92. Relative abundance of aphid species differed somewhat during the three years. *Myzus persicae* (Sulzer) was by far the most abundant species throughout the period, possibly because it is more attracted to yellow than some other species (A'Brook, 1973; Taylor and Palmer, 1972; Irwin, 1980; Halbert et al., 1981, 1986). Several species were under-estimated in the yellow pan water traps because they are not attracted to the colour. No *A. fabae* was recorded during 1991-92 season.

A total of 19 aphids were collected from the yellow pan water trap during April to June 1992 at Uyole Agricultural Centre in Tanzania.

Aphid/BCMV dynamics

During 1990-91 season, a trial was conducted on the dynamics of BCMV in relation to spread by aphids. The trial consisted of two large diagonally placed plots, replicated twice with two planting dates (early and late). The bean variety used was Carioca (black root susceptible). The plants with aphids/black root were recorded weekly from 2 weeks after emergence till harvest. These plots were located near the yellow pan water traps. The results showed that BCMV incidence was greaer in the late planting (7/2/91) than in the early one (27/1/90) (Table 5). Similar findings were reported by Sithananantham et al., (1990). The increase in BCMV incidence could be due to the greater aphid activity in the later planting. Even at about 4 weeks after planting, the difference between early and late planting was significant. The seed yield in early planted plots averaged 1035 kg/ha, while under late planting it was only 317 kg/ha, and this reduction in yield was at least partly attributable to the greater extent of BCMV spread by aphid vectors in late planting. A similar trial was conducted in 1991-92 season, but it was affected by the drought and hence no results were obtained.

BCMV-Aphid transmission studies

A preliminary study was conducted in the screenhouse to compare the relative efficiency (percent success) of transmission of BCMV by three aphid vectors, *A. craccivora, A. fabae* and *A. gossypii*. Aphid species of *A. craccivora, A. fabae* and *A. gossypii* were reared on potted cowpea (cv. Muliana), beans (cv. Carioca) and *Hibiscus* sp., respectively. The aphid cultures were maintained in cages (1x1x1m) placed in the screenhouse. The second generation of apterous aphids were used for transmission studies. We planted 2-4 seeds of Carioca/pot and thinned them to 1 plant/pot one week after emergence (WAE). Fine-tipped camel's hair brushes were used to transfer nymphs and adults. The apterous adults of *A. craccivora, A. fabae* and *A. gossypii* were starved for 1 hour before transmission. The aphids were permitted to acquire the virus by feeding on 2 week old bean cv. T3, which is highly susceptible to BCMV. They were allowed acquisition feeds of less than 60 secs. The aphids were transferred to healthy test plants of Carioca (2 WAE) for 3 minutes of inoculation access feeding/probing and later aphids were removed from the test plants. The test plants showing black root symptoms were recorded daily for a period of 3 weeks after aphid inoculation. Results are shown in Table 6. *A. fabae* and *A. craccivora* were more efficient in transmitting BCMV than *A. gossypii*. The higher the number of aphids per plant (3-4) the more successful the transmission, especially true for *A. craccivora* and *A. fabae*. It is also evident from the results that all three aphid vectors were capable of trasmitting BCMV. Attempts to rear *M. persicae* in the screenhouse were unsuccessful.

BCMV strain identification

The bean leaf samples showing BCMV symptoms were collected from farmers' fields in two districts (Chipata and Chadiza) of the eastern province, Zambia. Fourteen samples were collected along the motorable roads using the calcium chloride method. BCMV strains were identified by Drs. Spence and Walkey of Horticulture Research International, Wellesbourne, U.K. The bean leaf samples were inoculated on to susceptible bean seedlings, and later inoculations on to differential cultivars was carried out. The enzyme-linked immunosorbent assay (ELISA) was run on the dried sample using two monoclonal antibodies from Dr. Gaylord Mink (Prosser, WA, USA). The monoclonals were 197, which is a broad-spectrum antibody for BCMV (all strains) but which also cross reacts with blackeye cowpea mosaic virus, and I2, which is specific only for "A" serotype BCMV strains (NL3, NL5 and NL8). "B" serotypes are the other 7 strains of BCMV. The results are shown in Table 7. Out of 14 isolates collected, 5 were identified by host differentials. 3 of them were identified as NL3 and 2 as NL6. Earlier work in Zambia by Kannaiyan and Haciwa (1989) identified the BCMV strain NL3. Since the isolates were only collected in the medium rainfall (800-1200 mm) agro-ecological zone, perhaps more strains would be identified from the high rainfall (> 1500 mm) agro-ecological zone. Further sampling should be carried out in other bean growing areas of Zambia.

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Table 1. Survey for *Aphis fabae* infestation in farmers' bean crops in Zambia, 1989-91.

Province	District	Total Surveyed	Aphid Infested	Plant stand per m^2	Plants inf. by aphids per ha	%
I. High rainfall zone (1200 mm) April 1989 (Main season) :						
Luapula	Samfya	1	1	4	12,400	31
"	Mansa	5	5	4 (3-5)	21,200	53 (30-67)
Northern	Luwingu	1	1	4	10,800	27
"	Mbala	1	1	3	12,000	40
	Overall	8	8	4 (3-5)	17,650	46 (27-67)
II. High rainfall zone (> 1200 mm) April 1991 (Main season) :						
Luapula	Mansa	4	1	8 (4-12)	4,400	3 (0-12)
"	Chinsali	3	2	8 (5-12)	6,400	8 (0-16)
Northern	Isoka	4	1	8 (4-12)	1,800	2 (0-8)
"	Mbala	9	5	21 (6-40)	9,640	5 (0-20)
"	Mporokoso	3	3	13 (10-15)	5,060	4
	Overall	23	12	14 (4-40)	6,157	4 (0-20)
III. Medium rainfall zone (800-1200 mm) April 1989 (Main season):						
Central	Serenje	1	1	4	7,600	19
Eastern	Chipata	4	1	36 (21-56)	10,800	3 (0-10)
"	"	3	3	11 (6-14)	61,600	56 (43-83)
	Overall	8	5	23 (4-56)	29,450	25 (0-83)

Table 2. A survey on extent of seed-borne BCMV in farmers' bean seeds in three bean growing provinces in Zambia, 1989-91.

Province	Samples examined	No. (%) samples with seed-borne BCMV	Extent of seed-borne BCMV in individual samples (%) Maximum	Mean
Eastern	39	16 (41)	25.8	2.4
Northern	29	14 (49)	14.3	3.7
Northern-western	88	15 (75)	30.8	6.1
Overall	88	45 (51)	30.8	3.7

Table 3. Effect of intercropping bean (cv. Misamfu Speckled Sugar) with maize on the incidence of BCMV and colonization by *Aphis fabae* at Msekera, Zambia, 1989-90.

Cropping pattern maize:bean	BCMV (cumulative)			Aphid colonies					
	22Feb	21Mar	10Apr	22Feb	1Mar	7Mar	17Mar	21Mar	Mean
2:1	5.7	15.1	20.4	3.3	5.9	1.2	0.6	0.5	2.2
1:1	7.1	16.0	23.1	12.2	14.1	1.9	0.9	0.5	5.9
1:2	8.0	22.8	30.9	5.0	5.8	0.1	0.3	0.4	2.3
0:1	8.2	29.7	37.6	17.0	17.6	0.6	3.0	1.3	7.9
Mean	7.3	20.9	28.0	9.4	10.9	1.0	1.2	0.7	
S.E. ( )	1.0	2.0	2.1	1.9	2.2	0.6	0.7	0.4	0.8
C.V.(%)	33.4	23.1	18.0	51.0	50.0	165.0	138.6	134.2	44.4

Table 4. Aphid species collected in yellow pan water traps kept in bean fields at Msekera, Zambia, 1989-92.

Aphid species *	Aphids caught/trap		(Percent)
	1989-90	1990-91	1991-92
Aphis craccivora Koch	28 (11.6)	7 (1.5)	69 (2.3)
A. fabae Scopoli	13 (5.4)	2 (0.4)	-
A. gossypii Glover	11 (4.6)	1 (0.2)	86 (2.9)
A. spiraecola Patch	16 (6.6)	28 (6.0)	28 (0.95)
Brevicoryne brassicae (L.)	-	-	22 (0.75)
Hallaphis sp.	-	-	1 (0.03)
Hysteroneura setariae (Thomas)	-	-	4 (0.13)
Lipaphis erysimi (Kaltenbach)	-	-	37 (1.26)
Melanaphis sacchari (Zehntner)	-	1 (0.2)	17 (0.58)
Myzus persicae (Sulzer)	156(64.7)	416(88.7)	2607(88.7)
Rhopalosiphum maidis (Fitch)	2 (0.8)	10 (2.1)	29 (0.98)
Schoutedenia lutea (van der Goot)	-	2 (0.4)	10 (0.34)
Tetraneura nigriabominalis (Sasaki)	-	1 (0.2)	6 (0.2)
Toxoptera citricidus (Kirkaldy)	-	1 (0.2)	-
Uroleucon compositae (Theobald)	-	-	1(0.03)
Undetermined	15(6.2)	-	21(0.68)
Total	241	469	2938

* Aphid species identified by A. Autrique, Corroy-de-Grand, Belgium.

Table 5. Incidence of BCMV, pod set and bean seed yield in Carioca planted early and late at Msekera, 1989-90.

% plants with BCMV (Black root)	Early[1]	Late[2]	CV %	SE (m)	LSD (0.05)
26 DAP *	0.4	26.3	35.4	1.1	3.3
33 "	0.2	16.4	33.6	0.7	2.0
40 "	2.3	13.3	46.5	0.9	2.6
47 "	2.3	11.0	33.7	0.5	1.6
54 "	5.7	11.2	27.7	0.6	1.6
Overall (cumulative)	11.0	78.5	20.0	-	-
Pod set score (1-9 scale)	6.5	3.9	18.8	0.2	0.7
Seed yield (kg/ha)	1035	317	30.1	48.8	143.1

* DAP = Days after planting
[1] Early = planted on 27/12/90
[2] Late = planted on 7/2/91

Table 6. Transmission of the bean common mosaic virus by *A. craccivora*, *A. fabae* and *A. gossypii* at Msekera, Zambia.

Aphid species	Number of aphid(s) per plant				
	0	1	2	3	4
Aphis craccivora Koch	0/24[a]	3/24[b] (12.5)	1/24 (4.2)	5/24 (20.8)	6/24 (25.0)
A. fabae Scopoli	0/12	1/12 (8.3)	1/12 (8.3)	2/12 (16.3)	4/12 (33.3)
A. gossypii Glover	0/24	1/24 (4.2)	0.24 (0.0)	1/24 (4.2)	1/24 (4.2)

Figures in parentheses are % plants with black root
[a] Control (no aphids)
[b] Black root plant(s)/total exposed

Table 7. Reaction of bean differential leaf samples to BCMV collected from the two districts of eastern Province, Zambia, 1992.

Sample	Location	Monoclonal antibody		Serotype	BCMV strain
		197	I2		
1.	Msandile	+	-	B	
2.	Chalumbe	+	-	B	
3.	Msandile	-	-		
4.	Lutembwe	+	-	B	NL6
5.	Jerusalemu	+	-	B	NL3
6.	Jerusalemu	-	-		
7.	Thanila	+	+	A	NL3
8.	Mangwe	+	+	A	NL6
9.	Selemani Village	-	-		
10.	Kalichero	-	-		
11.	Kalichero	-	-		
12.	Mugabe Village	-	-		
13.	Mteleza Village	-	-		
14.	Msekera	+	+	A	NL3

THE ESTABLISHMENT OF BEAN COMMON MOSAIC VIRUS DISEASE RESISTANCE NURSERIES THROUGH COLLABORATIVE RESEARCH IN EASTERN AND SOUTHERN AFRICA

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ABSTRACT

A project to establish bean common mosaic virus (BCMV) disease resistant nurseries in the countries of eastern and southern Africa was approved for funding in 1989. The objectives of the project include :(a) survey and identify BCMV strains in Ethiopia, Tanzania, Uganda, Zambia and Zimbabwe; (b) evaluate/screen germplasm collections against the prevalent strains at "hot spots" in the countries of the two regions; (c) conduct comparative studies of pathotypes against promising materials within the region and (d) identify possible existing BCMV strains in alternate leguminous hosts. Studies carried out so far indicate that : (i) with the exception of Ethiopia, BCMV-NL3 (black-root) is the predominant and most important strain in the countries of the two regions. Based on this strain identification, a map showing geographical and ecological distribution of strains seems desirable both to guide seed movement and deployment of resistance against these strains; (ii) alternate leguminous hosts carrying BCMV strains have been identified; and that (iii) certain bean materials have been identified to show resistance against predominant strains in the participating countries. The implications of these results, as recently and extensively discussed by the project working group, warrant further investigation, but with stringent priorities set under a wider Pan-African Network Programme that will successfully manage the disease within the continent.

INTRODUCTION

Bean common mosaic virus (BCMV) is an important pathogen of beans in most countries in Africa. Unlike the situation with fungal and bacterial diseases where there is an array of chemicals that can control them, no chemicals have been found for the control of BCMV. Breeding for resistance is the only feasible way to control BCMV. Resistance to BCMV is imparted by recessive strain-specific genes or by the dominant I-gene (Drijfhout, 1978). The deployment of the

I-gene has been very successful in Latin America. Temperature-insensitive or necrosis-inducing (necrotic) strains of BCMV have been reported in Europe, Africa and the USA that have overcome I-gene resistance and induce systemic necrosis. Drijfhout (1978) found that I-gene cultivars were not killed by necrotic strains, if either of the genes bc 2-2 or bc-3, or both, are incorporated to protect the I-gene.

Surveys to identify BCMV strains prevalent in Africa have established that, with the exception of Ethiopia, NL3, a necrotic strain, is the predominant strain in the countries of eastern, central and southern Africa (Spence and Walkey, 1991a). This implies that the deployment of I-gene cultivars is not a sound strategy in Africa. Weed legumes have also been found to carry strains of BCMV (Spence and Walkey, 1991b). Information generated on such a study is important because it indicates the risk that unknown strains in wild reservoirs could be transmitted by aphids to beans. This information has a bearing on the breeding strategy to be employed.

A collaborative research network is being established on a Pan-African basis to address the problem of BCMV in a multidisciplinary manner, with input also of an entomologist (P.H. Sohati, Zambia) and another pathologist (A. Gubba, Zimbabwe) to supplement our own disciplines, of virology, breeding and pathology, respectively. The objectives of the project are : to breed for resistance to BCMV by incorporating the recessive bc 2-2 and/or bc-3 genes into bean cultivars at the pre-release stage; to monitor the evolution of possible new strains that can overcome the bc-3 gene resistance; to determine importance of wild legumes as reservoirs of the necrotic strains of BCMV; and to study other mechanisms of resistance to BCMV such as the exploitation of variation in seed transmission rates, vector non-preferences, and BCMV resistance in land-races.

METHODOLOGY

Breeding for resistance to BCMV (Mukoko)

This will be done by incorporating by backcrossing either the bc-3 gene or the bc 2-2 gene into bean cultivars that are at the pre-release stage in national programmes. BCMV resistant cultivars carrying these recessive genes will be obtained from CIAT. All resultant progeny will be screened for resistance to the NL3 strain of BCMV. These materials will be sent to the respective national bean programmes for yield testing in the field.

Strain monitoring (Lana)

In order to monitor the emergence of recessive resistance (bc-3, bc 2-2) breaking strains, an 'early warning package' or nursery will be put together. This nursery will comprise material possessing the I-gene, some with the bc 2-2 gene, bc-3 gene and some without the I-gene, and will be grown at BCMV 'hot spots' in different countries, every season. This nursery will be evaluated for BCMV by collecting leaf materials which will be sent to the Tanzania investigator for strain identification, using ELISA and differential/cultivars.

Wild reservoir of BCMV (Gubba and Sengooba)

A study on the role of wild leguminous plants as alternate hosts of BCMV is already in progress in Uganda. Work on wild legumes will be intensified to cover southern Africa. Leguminous plants in the vicinity of bean fields will be sampled and BCMV strain identification will be undertaken using ELISA, bean differential cultivars and electron microscopy.

Other mechanisms of resistance

Seed transmission (Lana and Sengooba)

Non-I gene cultivars will be screened for seed transmission rates of BCMV, with the hope of identifying cultivars that possess a 'resistance' to seed transmission of BCMV. All plants of the cultivars to be screened will be manually inoculated with the NL3 strain of BCMV at the unifoliolate leaf stage. The plants will be grown to maturity. Seed harvested will be replanted and seedlings will bbe tested for the presence or absence of BCMV. This activity will be confined to the glasshouse.

Vector non-preferences (Sohati)

Cultivars will be screened for vector non-preference. Alighting responses will also be studied.

BCMV resistance in landraces (Lana, Sengooba, Mukoko and Sohati)

A study in Uganda has already indicated that there may well be resistance to BCMV in a few landraces. Consequently, landraces will be collected from national programmes and screened for resistance to BCMV.

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BREEDING BEANS (PHASEOLUS VULGARIS L.) FOR RESISTANCE TO BEAN COMMON MOSAIC VIRUS IN ZIMBABWE

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ABSTRACT

Bean common mosaic virus (BCMV) causes one of the most important diseases limiting bean yields in Zimbabwe. Breeding for resistance is the only feasible way to control BCMV, but resistance must be combined with other characteristics of agronomic and culinary importance, if the resistant cultivars are to be accepted by farmers and consumers. A survey to establish bean production practices and constraints revealed that, in Zimbabwe, the large seeded cranberry type was the most widely grown. Monotypes of seed, rather than mixtures are widely grown and beans are grown mainly in monoculture rather than in intercrop systems. Strain identification revealed that at least three strains of BCMV (NL1, NL3 and NL6) occur in Zimbabwe and that necrosis-inducing strains were the most prevalent. Experiments conducted to estimate yield loss due to BCMV demonstrated that BCMV infection reduced seed yield by about 20%, early infection reducing yields the most. A backcrossing programme to incorporate the bc-3 gene for resistance to BCMV was followed. The selfed backcross progenies were evaluated for agronomic and consumer characteristics. The large seed size of the recurrent (standard) parent was consistently and easily recovered. These results, and those from an experiment to test the effect of selection for BCMV resistance and other characters, suggested that in breeding for resistance to BCMV, it would be relatively easy to recover the preferred large seed types. There also appeared to be a favourable linkage between BCMV resistance and fast cooking characteristics.

INTRODUCTION

Beans are a preferred grain legume in Zimbabwe and are widely cultivated by small-scale subsistence farmers. The cultivars currently grown are susceptible to a number of diseases, among which BCMV is one of the most important. Unlike the situation with fungal and bacterial diseases where there is an array of chemicals that can control them, no chemicals have been found for the control of BCMV. Breeding for resistance is the only feasible way to control BCMV. Resistance to BCMV is imparted by recessive strain-specific genes or by the dominant I gene (Drijfhout, 1978). The I gene resistance is due to a hypersensitive host reaction at normal growing temperatures and is expressed as necrotic local lesions or restricted spreading veinal necrosis. At temperatures above 33°C, lethal systemic necrosis or blackroot occurs. The I gene also prevents seed transmission of BCMV. The deployment of the I gene has been very successful in most parts of the world, notably in Latin America and the USA. Temperature-insensitive or necrotic strains of BCMV have been reported in Europe, Africa and the USA that have overcome the I gene resistance and can induce blackroot at normal growing temperatures (Drijfhout, 1978; Innes and Walkey, 1979; Silbernagel et al., 1986; Davis et al., 1987). The predominance of these strains in East, Central and Southern Africa has necessitated the adoption of different strategies in breeding for BCMV resistance. Drijfhout (1978) found that dominant I genotypes are not killed by necrotic strains if either of the genes bc2-2 or bc3, or both, are incorporated to protect the I gene. Plants possessing the I gene plus bc2-2 develop local pinpoint lesions when attacked or inoculated with a necrotic strain of BCMV, whilst plants possessing the I gene plus bc3 do not develop any symptoms and thus show an immune response.

Work reported in this paper is part of a PhD dissertation on breeding beans for resistance to BCMV in Zimbabwe. The core of this project was breeding to incorporate resistance to BCMV into bean cultivars suitable for Zimbabwe by backcrossing, and to study the progenies generated from the programme to determine the ease with which BCMV can be combined with characteristics required for field adaptation and consumer preferences in Zimbabwe. Around this core were various auxiliary activities.

Firstly, a survey to obtain information on bean production systems, cultivars grown and productivity constraints was carried out in the main bean producing districts of Zimbabwe. Knowledge of strains of BCMV is a necessary pre-requisite in any BCMV resistance breeding programme. The identification of BCMV strains prevalent in Zimbabwe was carried out. Knowledge of the severity of a disease is another important pre-requisite for breeding, and yield losses caused by BCMV at different stages of plant growth were estimated in field and glasshouse experiments.

SURVEY OF BEAN PRODUCTION IN ZIMBABWE

Methods

A survey was designed and carried out in bean producing areas all over Zimbabwe to obtain information on production systems, cultivars grown and productivity constraints at the farm level. Tolerances to biotic and abiotic stress were scored on a simple scale of 1 = low, 2 = average and 3 = high. Questionnaires were sent to extension officers stationed in 23 districts across Zimbabwe. Extension officers were asked to interview 5 farmers per district and to collect small samples of seed of the cultivars grown. Sixty-nine small-scale farmers took part in the survey. Frequency distributions of the responses to each question were obtained. Chi-squared tests of association were also carried out.

Results

Beans were found to be predominantly grown as a sole crop (61% of farmers) although some intercropping with maize (38% of farmers) was practised. This observation is unlike most African cropping systems where a large proportion of beans is grown in mixtures with maize and/or other crops. Bush and semi-climbing types are the most cultivated, both types being grown in natural regions 1 and 2 and semi-climbers in the drier natural regions 3 and 4.

A great diversity of large seeded cultivars is grown by farmers, a large seeded cranberry type (cream with red mottles) being the most widely grown. Monotypes are more widely grown than mixtures of seed types. The crop is perceived by farmers as having inadequate levels of resistance to diseases, pests, low soil fertility, drought and competition with weeds. These perceptions are broadly consistent with the conclusion of research workers.
It was apparent from this survey that, if improved cultivars are be accepted by farmers and consumers, they should be large seeded, preferably of a cranberry type and suitable for cultivation in monoculture.

IDENTIFICATION OF BCMV STRAINS

The objective of this study was to identify BCMV strains prevalent in Zimbabwe and to produce a map of their distribution.
Strain identification in a country is a necessary pre-requisite in any virus resistance breeding programme. This is because it enables the breeder to determine the resistance genes that must be incorporated and the most suitable strain(s) for the screening of germplasm and progeny.

Materials and methods

Three disease surveys to collect samples of <u>Phaseolus vulgaris</u> suspected to be infected with BCMV for strain identification were carried out in important bean growing regions of Zimbabwe in 1989, 1990 and 1991. Samples collected were in one of three forms: a) fresh leaf samples b) dehydrated leaf samples preserved by desiccating on cotton wool over anhydrous calcium chloride in an air-tight plastic vial c) mature dry seed. To identify the BCMV strains present in the samples, the isolates were inoculated onto the standard set of differential bean cultivars (Drijfhout, 1978). The differentials were raised in pots in the glasshouse and sprayed once or twice weekly with pirimicarb, a fast-acting specific aphicide with contact respiratory and systemic action, to prevent secondary spread of BCMV through controlling the vector.

Sap inoculum was prepared by grinding the leaf sample in phosphate buffer according to the method described by Walkey (1985). Seedlings of the differential cultivars whose primary leaves had just unfolded (about 3 days from emergence) were then inoculated. Four out of five plants of each differential cultivar were inoculated with each isolate and the fifth plant, which was the control, was inoculated with phosphate buffer only. Plants were left in the glasshouse for 4 weeks and were observed twice weekly for symptoms. Conclusion on the identity of a strain was made by observing the type of symptoms produced on each of the differential cultivars and comparing them with those of strains already identified and documented.

Results and discussion

None of the dried leaf samples (preserved over calcium chloride) showed any BCMV symptoms upon sap transmission onto universally susceptible cultivars. This suggests that the virus had deteriorated in storage. The failure of this method highlighted the need for more investigation on the optimum period and storage of BCMV over calcium chloride.

It is apparent that at least three strains of BCMV occur in Zimbabwe and that necrotic strains predominate. Out of the 15 samples from which BCMV was detected, eight contained a strain which behaved like NL3, three contained a strain which behaved like NL6 and four had a strain that behaved like NL1. Figure 1 shows the geographical distribution of the strains. Results obtained here are in agreement with other reports of strain typing in Tanzania (Silbernagel et al. 1983; Mink, 1984; 1985), Kenya (Silbernagel et al., 1986; Mink, 1985), Rwanda and Burundi (Davis, 1989) and Uganda (CIAT 1989; Spence and Walkey, 1991) where high incidence of necrotic strains of BCMV have been found. Vetten and Allen (1991) using serological techniques, found both necrotic and non-necrotic types in Zimbabwe.

The implication of these results is that the deployment of the unprotected I gene is probably not a sound strategy in Zimbabwe. However, most improved cultivars and progenies carry the dominant I gene. Thus, its protection should be a priority. Several different strategies can be followed in breeding for BCMV resistance in Zimbabwe:

- incorporating both bc3 and bc2-2 genes in I gene cultivars
- incorporating the bc3 gene on its own. The bc3 gene cannot be overcome by any known virus strain.
- deployment of the bc2-2 gene on its own, but only in areas where NL4 strain does not exist (which appears to

be the case in Zimbabwe).

The presence of the NL1 strain does not alter the breeding strategy discussed above, because cultivars susceptible to NL1 are also susceptible to NL3, whereas cultivars resistant to NL1 are not necessarily resistant to NL3. As with NL3, the only secure way to prevent temperature-dependent systemic necrosis induced by NL6 is to protect the I gene. Therefore, in breeding for BCMV resistance in Zimbabwe, it is necessary to screen the breeding material against strain NL3, or a combination of strains NL3 and NL6.

YIELD LOSS ASSESSMENT

Experiments were then designed to:

(a) estimate the effect of NL3 and NL6 strains and their interaction on the yield of beans and components of yield
(b) assess the extent of virus damage at various stages of growth
(c) determine the degree of correspondence between field and glasshouse results.

Materials and methods

Natal Sugar and Red Canadian Wonder were the cultivars used in this study. They do not carry the dominant I gene for BCMV resistance and hence do not develop systemic lethal necrosis, thus making it possible to make comparisons between different strains without affecting plant population. The disadvantage of using such $I^+ I^+$ cultivars is that there is no guarantee of freedom from seed-borne BCMV. Seed used in this experiment was the product of intensive roguing against infected plants. Other treatment factors were inoculation (presence or absence), time of inoculation, viz:

a) inoculation at primary leaf stage (time 1)
b) inoculation at three to four trifoliolate leaf stage, approximately 17 days after emergence (time 2)
c) inoculation at the flowering stage (time 3)

and strain of BCMV, viz:

i) inoculation with NL3 only
ii) inoculation with NL6 only
iii) inoculation with NL3 + NL6

Two experiments to study the effect of strain and time of inoculation on yield and yield components of beans were carried out, one in the field and the other in the glasshouse.

Results

The results from field and glasshouse experiments were similar for percent yield reduction for the two cultivars (Table 1).
It was apparent from these results that the effect of BCMV on yield was not evenly distributed among the three yield components. The effect was evenly distributed between pods/plants and seeds/pod and there was a very small effect on weight/seed. Both experiments also demonstrated that time of inoculation had significant effects on seed yield and yield components (Table 2), early inoculation reducing yield the most. Hence, the age of the crop at the time of infection is probably the main determinant of yield loss due to BCMV. Since the experiments clearly showed that early inoculation is most damaging, control measures for BCMV should be aimed particularly at the prevention of early infection, and seed transmission of BCMV is the most important factor responsible for early infection. The development of resistant cultivars is the only feasible way of controlling BCMV and of preventing seed transmission.

BREEDING FOR RESISTANCE TO BCMV

Materials and Methods

In order to incorporate the bc3 gene (which is resistant to all known strains of BCMV) into Zimbabwean cultivars, a backcross breeding strategy was followed. Six lines resistant to BCMV (MCM 3030, MCM 2001, MCM 1018, MCM 5001, MCM 5002 and MCM 2004) obtained from CIAT were backcrossed to five standard cultivars (Red Canadian Wonder, Natal Sugar, A86, Carioca and Puebla 152 Cafe). All the resistant lines carried the I + bc3 gene combination and were small seeded. Up to three cycles of backcrossing were completed. After each cycle, a generation of selfing was carried out, during which plants were inoculated with a mixture of BCMV strains NL3 and NL6, in order to identify plants carrying the bc3 gene, which were symptomless. Only these symptomless plants were used as parents for the following backcross. The crosses made are shown in Table 3. The standard and resistant parents, P1 and P2 respectively, and the selfed progeny of the three cycles, B1s, B11s and B111s respectively, were then tested in the field. Time to flowering and maturity were recorded, and seed yield and seed size were measured. Cooking time was measured using a Mattson cooker.

Results

The large seed size of the recurrent parents was consistently easily recovered (Table 4), indicating that breeding for the preferred large seed size is not going to be difficult in a backcross programme that aims to transfer resistance to BCMV. The early flowering of the recurrent parents, on the other hand, was recovered in some crosses but not in others (Table 4), and similarly variable results were obtained for days to maturity (Fig.

2). The resistant cultivars had shorter cooking times than the standard cultivars, but long cooking time was not generally recovered (Table 5). This result may reflect a favourable linkage, since fast cooking is preferable, but should be treated with caution since the test was conducted on fresh seed, and cooking time is affected by hardening during storage, to different extents in different genotypes. Moreover, cooking time is more prone to error variation than seed size or flowering time. The yields of the resistant cultivars were generally higher than those of the standard parents, but there was no consistent pattern in the yields of the progeny.

TEST OF SEED CHARACTERS IN THE F3 GENERATION

F3 families (the progeny of F2 single plants) of the 24 crosses were analysed for seed characters and resistance to BCMV and inferences were made on predictability of F3 values from parental values. This was done by regressing cross means on the means of the two parents. Variation between the crosses was thus divided into 2 components: one due to regression and the other due to deviations from this regression. Inferences were also made on predictability of the within-cross variation from the difference between parents, by regressing the cross standard deviation on the difference between parent means. For seed size and seed shape, the regression component was significant and hence, the cross means could be largely predicted from the means of the parents. However, the significant deviations from regression component implied that the cross means could not be totally predicted from the means of the parents. The regression component though accounted for most of the variability. Variability in seed size of the crosses could be largely predicted from the difference between parent means, but there were some deviations from predictions.

THE EFFECT OF SELECTIONS FOR BCMV RESISTANCE ON OTHER CHARACTERS

The aim of this experiment was to investigate the effect of selection for BCMV resistance on other agronomic characters, in six crosses. One set of 50 F3 families per cross was grown at Kadoma where plants were inoculated with a mixture of NL3 + NL6 strains of BCMV. At maturity, F4 seed of symptomless plants was harvested for each line. These families were thus exposed to a cycle of selection for BCMV resistance. For another set of 50 F3 families per cross, four F3 plants of each family where grown in the glasshouse in as disease-free an environment as possible, with weekly sprays against aphids (unselected families). F4 seed of each family was harvested separately and sown in the field alongside seed of the selected families which had been harvested in the field at Kadoma. Seed size of each family was measured before sowing. It was observed that in general, selected families tended to flower and mature later than the unselected families (Table 6) However, the differences between selected and unselected families were very small and unlikely to be of much practical significance.

Selecting for BCMV resistance had a positive effect on seed size, selected families having larger seed size than the unselected (Table 6). This result, together with observations made in the backcross programme, indicates that it may be relatively easy to recover large-seeded, BCMV resistant types.

CONCLUSION

The results obtained in this study indicate that there are good prospects for developing BCMV resistant cultivars that possess the characteristics required for utilization in Zimbabwe i.e early maturing, large seeded types possessing fast cooking characteristics. Incorporating the recessive strain-specific bc3 and/or bc2-2 gene(s), either separately or in combination with the I gene, are probably the only strategies that will control BCMV in Zimbabwe and other bean producing countries where necrotic strains are prevalent.

ACKNOWLEDGEMENTS

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Table 1: Mean effect of BCMV infection on yield and yield components

	Component	Healthy	Infected	% Reduction
Glasshouse	Pods/plant	6.08	5.47	10.0
	Seeds/pod	4.47	3.98	11.0
	Seed size (mg)	371.6	370.7	0.2
	Yield (g/plant)	9.74	7.77	20.2
Field	Pods/plant	10.25	9.50	7.3
	Yield (g/m2)	714.9	567.5	20.6

Table 2: Mean effect of time of BCMV inoculation on yield and yield components

	Component	Healthy	Time 1	2	3	% Reduction 1	2	3
Glass-house	Pods/plant	6.08	5.21	5.21	5.99	14.3	14.3	1.5
	Seeds/pod	4.47	3.77	3.93	4.25	15.8	12.1	5.0
	Seed size (mg)	371.6	376.8	380.7	354.7	1.4	-2.5	4.6
	Yield (g/plant)	9.74	7.11	7.49	8.72	27.0	23.1	10.5
Field	Pods/plant	10.25	9.42	9.33	9.75	8.1	9.0	4.9
	Yield (g/m2)	714.9	484.4	579.8	638.3	32.2	18.9	10.7

- = negative reduction = increase

Table 3: Crosses made successfully and backcross generations produced

Recurrent parent (maternal) P1	MCM 3030	MCM 2001	MCM 1018	MCM 5001	MCM 5002	MCM 2004
Red Canadian Wonder	B1 B11 B111	-	B1 B11 B111	B1	B1 B11 B111	-
Natal Sugar	B1	B1	B1 B11 B111	B1	B1	-
Carioca	B1 B11 B111	B1 B11 B111	B1	-	B1 B11 B111	B1 B11 B111
A86	B1 B11 B111	B1 B11 B111	B1 B11 B111	-	B1	B1 B11 B111
Puebla 152 Cafe	B1	B1 B11 B111	B1 B11 B111	B1 B11 B111	-	B1 B11 B111

Table 4: Quantitative characteristics in backcrosses of BCMV resistant cultivars to standard cultivars.

Cross	P1	P2	B1s	B11s	B111s
a) Seed size (mg)					
RCW x MCM 3030	389.0	185.5	305.5	373.0	384.5
RCW x MCM 1018	389.0	226.5	296.0	352.0	386.0
RCW x MCM 5001	389.0	237.0	312.5	-	-
RCW x MCM 5002	389.0	225.0	313.0	326.5	350.0
Natal Sugar x MCM 3030	346.5	185.5	303.5	-	-
Natal Sugar x MCM 2001	346.5	226.5	375.0	-	-
Natal Sugar x MCM 1018	346.5	226.5	329.5	403.5	371.5
Natal Sugar x MCM 5001	346.5	237.0	353.5	-	-
Natal Sugar x MCM 5002	346.5	225.0	352.5	-	-
(LSD) = 44.6					
b) Days to flowering					
RCW x MCM 3030	34	43	35	39	42
RCW x MCM 1018	34	48	47	35	39
RCW x MCM 5001	34	45	34	-	-
RCW x MCM 5002	34	45	35	40	34
Natal Sugar x MCM 2001	42	46	45	-	-
Natal Sugar x MCM 5001	42	45	45	-	-
(LSD = 3.0)					

Table 5: Mean cooking time (minutes) of parents and backcrosses of BCMV resistance cultivars to standard cultivars

Cross	P1	P2	B1s	B11s	B111s
RCW x MCM 3030	48.5	28.5	31.5	24.5	28.0
RCW x MCM 1018	48.5	29.0	-	-	33.0
RCW x MCM 5002	48.5	38.0	29.0	31.0	28.5
Natal Sugar x MCM 3030	46.0	28.5	29.5	-	-
Natal Sugar x MCM 2001	46.0	32.5	32.0	-	-
Natal Sugar x MCM 1018	46.0	29.0	31.5	46.0	38.5
Natal Sugar x MCM 5001	46.0	29.5	30.5	-	-
(LSD = 7.11)					

Table 6: The effects of cross, selection for BCMV and their interaction on days to flowering, maturity and seed size (mg/seed)

Cross	Selected	Unselected
Days to flowering		
RCW x MCM 3030	43	38
Natal Sugar x MCM 3030	42	40
Carioca x MCM 3030	41	42
RCW x MCM 5002	42	41
Natal Sugar x MCM 5002	42	42
Carioca x MCM 5002	45	45
Mean	43	41
SED. 0.617		
Days to maturity		
RCW x MCM 3030	91	86
Natal Sugar x MCM 3030	90	90
Carioca x MCM 3030	87	86
RCW x MCM 5002	87	86
Natal Sugar x MCM 5002	89	89
Carioca x MCM 5002	87	86
Mean	89	87
SED = 0.631		
Seed size (mg/seed)		
RCW x MCM 3030	282.3	285.5
Natal Sugar x MCM 3030	278.1	289.2
Carioca x MCM 3030	220.0	220.0
RCW x MCM 5002	323.1	281.5
Natal Sugar x MCM 5002	322.0	317.1
Carioca x MCM 5002	261.2	235.3
Mean	281.0	271.4
SED = 6.02		

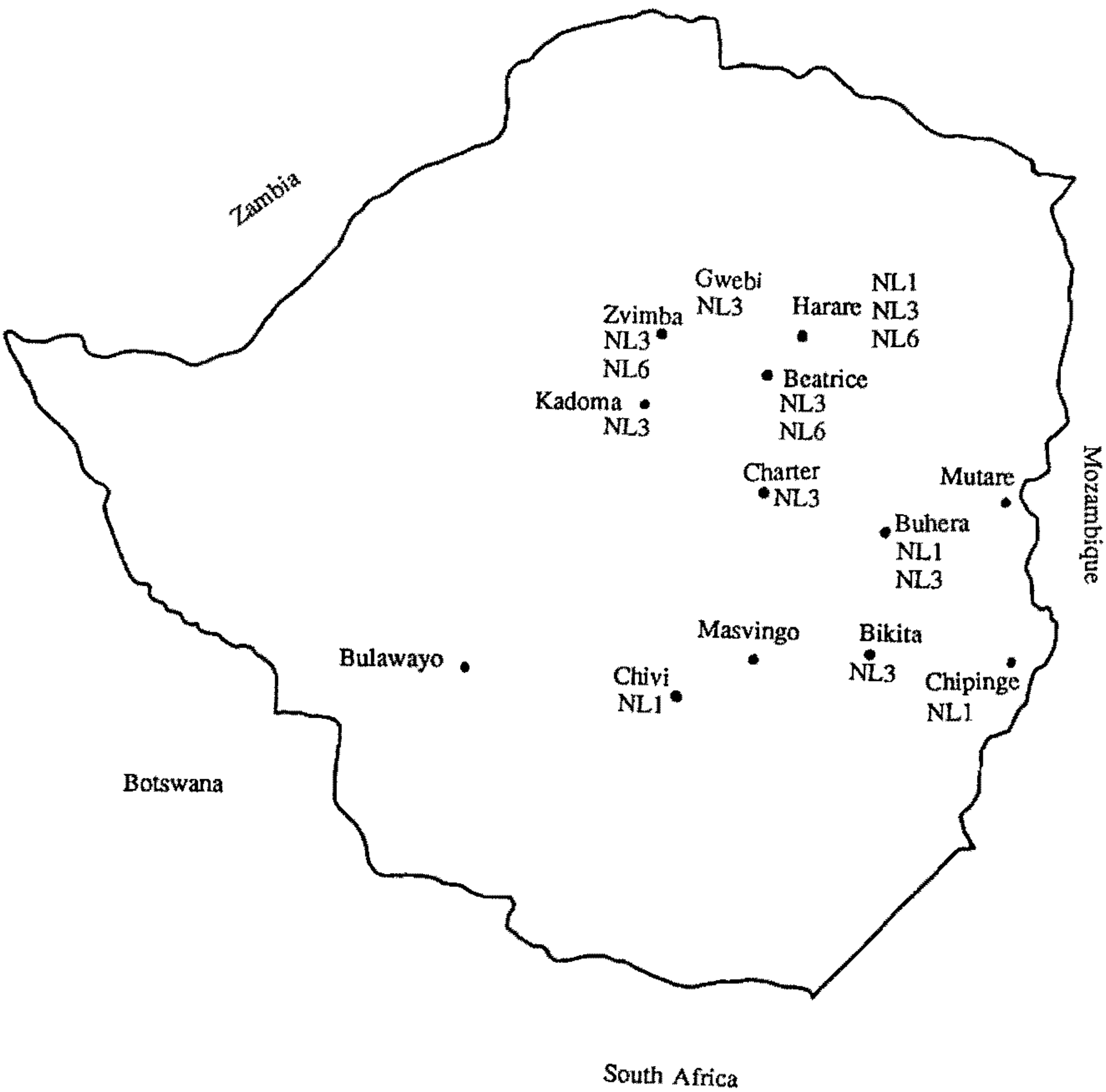
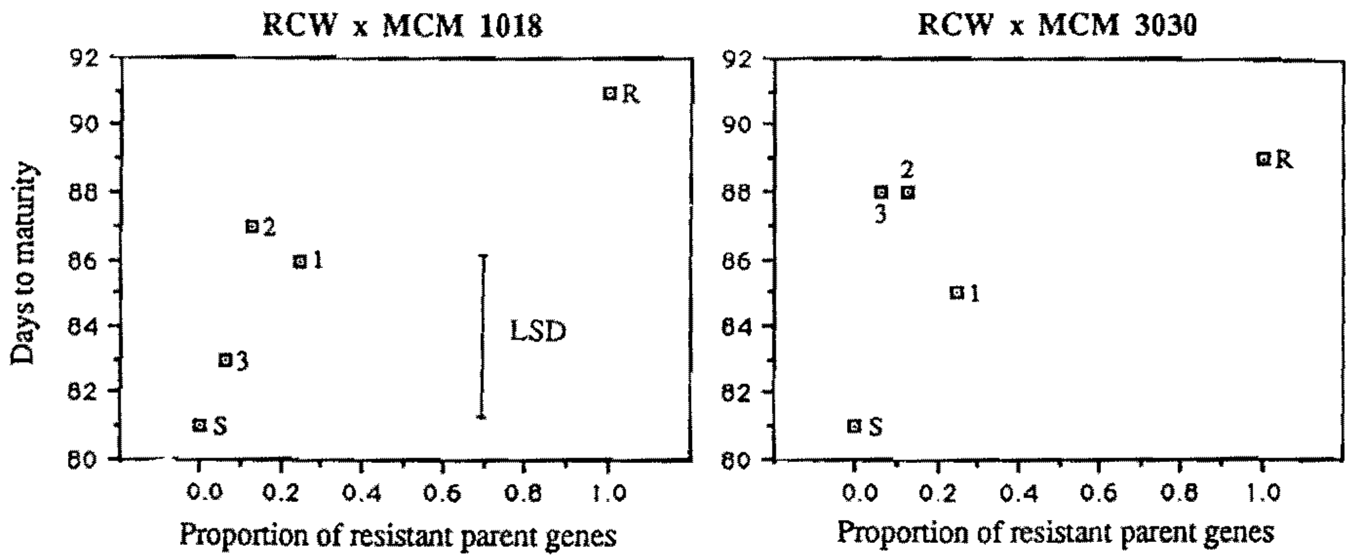


Figure 1. The geographical distribution of strains of bean common mosaic virus in Zimbabwe.

Figure 2. Days to maturity of parental and backcross generations of two crosses.



S = Standard parent

R = Resistant parent

1 = First backcross progeny

2 = Second backcross progeny

3 = Third backcross progeny

ADVANCES IN BEAN PATHOLOGY THROUGH NETWORK RESEARCH IN AFRICA

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ABSTRACT

This paper reviews the research progress made in pathology within the bean research network in Africa over the period 1985-92. Attention is drawn selectively to the most pertinent advances in preference to a fully comprehensive description of all work conducted in the region. A discussion of disease priorities on the basis of crop loss estimates is followed by a review of research highlights from the major diseases. The paper finishes with a critical review of progress towards integrated management and an appraisal of the principal gaps in knowledge now needing to be addressed.

INTRODUCTION

For the purposes of this paper, network research refers to studies undertaken by scientists within the national agricultural research system (NARS) of countries in central, eastern and southern Africa, by special projects cooperating with the NARS in Africa, and by CIAT scientists. Such work in some cases has been supported by the regional programmes of CIAT in Africa, through regional collaborative research sub-projects and scholarships for post-graduate degrees. Work that has received the support of the SADC/CIAT Regional Bean Programme is summarized in Tables 1 and 2, and Special Projects cooperating with the network are shown in Table 3. Priorities for network research are increasingly set at national planning workshops and, especially, at discipline-specific working group meetings at the Pan-Africa level. Those devoted specifically to bean pathology that have been held over the past five years are shown in Table 4.

PRIORITY OF BEAN DISEASES

Reviews of the principal bean diseases in Africa (Allen et al., in press), of progress in disease resistance breeding (Teri et al., 1990), and the place of disease among other production constraints of the crop (Allen et al., 1989) have been compiled recently. However, the extent to which diseases really do limit seed yield of the common bean in Africa remains surprisingly ill-defined.

Farmers' conceptual knowledge of "disease" is very scanty : it is almost always equated with "too much sun" or "too much rain", and "rain tolerance" is rated as an important varietal characteristic (Table 5). Among scientists, diseases are invariably ranked among the major constraints of the crop in Africa, as revealed by priority setting exercises during participative planning at the regional level (Table 6). But the true picture remains obscure. At a time when support for research continues to shrink despite obvious opportunities for making real impact on-farm, the need for accurate quantification becomes increasingly acute, for "how can we expect practical men to be properly impressed with the importance of our work and to vote large sums of money for its support when in place of facts we have only vague guesses to give them and we do not take the trouble to make careful estimates ? "(Lyman, 1918 cited by Wortmann, 1992).

Diagnostic trials conducted on-farm in Rwanda have demonstrated that soil infertility and disease were the two most important production constraints (Fig 1), and a clear negative interaction between soil fertility and disease is often found. Gains made through increasing soil fertility are offset by losses from increasing disease pressure, and if the farmer is obliged to choose between improving soil fertility and controlling disease, the latter is more likely to bring about significant yield increases (Graf and Trutmann, 1987). Multiple regression analysis has sometimes been used on data from variety trials to give qualitative estimates of the relative importance of a certain disease. Using such an approach, Greenberg et al., 1986, concluded that bean common mosaic (BCMV), angular leaf spot (ALS) and scab were the most important diseases in Zambia : BCMV in the warmer, hotter areas of Eastern Province; scab in the cooler, wetter areas of Northern Province; and ALS in both. More extensive analysis of sets of data from the African Bean Yield and Adaptation Nursery (AFBYAN) calls to question the importance of disease as a determinant of yield in the first place, as there were very few cases of significant associations between disease reactions and grain yield. CBB was recorded most frequently, but correlations with seed yield were negative in only two out of nine environments. ALS was recorded in eight environments and was negatively correlated with seed yield in three, with a significant positive correlation in one instance (Smithson, 1990).

Various studies have been conducted with specific diseases on research stations, as reviewed recently by Wortmann (1992). Re-analysis of data obtained by Gondwe (1989), working with anthracnose in northern Tanzania, has given the value of about 9 kg/ha loss in seed yield for a 1% increase in anthracnose severity. Similarly, for rust and angular leaf spot (Mmbaga, 1984), yield loss was estimated to be in the range of 2.9 - 5.6 kg/ha per unit increase in disease, but the effects of the two diseases cannot be differentiated, and the yields were in some cases very low. In studies on common bacterial blight in Uganda, it has been estimated that when severity was used as the parameter, yield loss for each 1% increase of disease ranged from 10.5 - 78 kg/ha depending on the season and stage of the crop (Opio et al., 1992). Wortmann (1992) suggests that, once such models have been determined and validated, results of disease surveys can be used to estimate the economic losses liable to result from given levels of disease, and this should assist in setting more solid priorities among diseases as constraints to productivity as a whole.

HIGHLIGHTS OF RESEARCH ON FUNGAL DISEASES

Anthracnose (*Colletotrichum lindemuthianum*) is the subject of regional collaborative research sub-projects whose progress and future direction has been reviewed recently, at a working group meeting in Ethiopia (Buruchara, 1991). Some studies in Kenya on the host-parasite relationship led to the race typing of 36 isolates, nine of which apparently did not conform in pathogenicity to any of the known races, although the "Are" gene in Cornell 49-242 was found immune to all isolates (Gathuru and Mwangi, 1991). Limited field observations in northern Zambia suggest that races beta, kappa and iota are absent, whereas the resistance of Widusa and the susceptibility of Mexico 222 Perry Marrow, Kaboon, Michelite and Michigan Dark Red Kidney implies the presence of races alpha-Brazil, lamda, alpha, delta and epsilon (Haciwa, 1991). Five races have been identified in Rwanda, where extensive screening has confirmed the resistance of a range of germplasm (Gasana, 1991). Surveys in Tanzania have led to the differentiation of 15 distinct isolates of *C. lindemuthianum*, none of which was pathogenic to the line G 2333 (Mwalyego, 1992a). Most of the isolates were able to attack Michigan Dark Red Kidney, Tu, To and Cornell 49-242. The types that appeared most virulent were also the most prevalent (Table 7). Whereas these studies confirm the variability of the anthracnose pathogen in Africa, the extent to which different races prevail in different areas remains unclear and some standardization of methodology seems warranted so as to compare results with greater confidence.

As regards angular leaf spot (*Phaeoisariopsis griseola*), studies on the variability of the pathogen and resistance in the host have been conducted both in Zaire by Pyndji Mukishi and in Malawi by W.A.B. Msuku and co-workers. One of the most interesting aspects of the studies by Pyndji (1988) is perhaps the evaluation of the protective effects of adding ALS resistant components to traditional mixtures of beans. When an ALS resistant variety is incorporated to make up only 25 per cent of the mixture, effective protection was given (Table 8; Pyndji and Trutmann, 1988).

Rust (*Uromyces appendiculatus*) has been the subject of intensive study in Ethiopia by Habtu Assefa whose PhD thesis may be expected to provide valuable new information. Work by Mmbaga in Tanzania has elucidated the spectrum of physiological races and has identified sources of resistance against them (Mmbaga and Stavely, 1988); more than 25 races are now recognized from Tanzania (M.T. Mmbaga, personal communication, 1992). Studies on the mechanisms underlying partial resistance to rust have shown that pubescence may play an important role (Mmbaga and Steadman, 1990).

Collaborative studies with the Research Institute for Plant Protection at Wageningen in the Netherlands has shown that the causal agent of ascochyta blight in Africa is *Phoma exigua* var. *diversispora* (Gerlagh, 1987). Evaluations of entries in an International Bean Ascochyta Blight Nursery in Rwanda, Uganda and Zambia have confirmed the existence of partial resistance which seems to be effective across locations (Allen et al., in press). Limited work on scab (*Elsinoe phaseoli*), principally in northern Zambia, has confirmed the existence of sources of resistance, including materials introduced recently from Latin America where the disease is apparently absent (Kannaiyan et al., 1990).

White mould (*Sclerotinia sclerotiorum*), whose importance in Africa is very seasonal and local, can cause significant losses in the northern highlands of Tanzania. Preliminary results from field screening for partial resistance indicate that white mould resistance identified in North America is also effective in Africa, where, to my knowledge, white mould resistance has not been sought before (Msuya et al., 1992). Among entries in a white mould nursery received from Nebraska, A 55 and Rabia de Gato appear outstanding. Interestingly, partial resistance of the same level was also found in at least eight other genotypes, including the landrace, Kiburu, which is widely cultivated on the slopes of Mount Kilimanjaro where white mould is a regular problem (Table 9).

Fungi associated with root rots of beans in the Great Lakes Region have been shown to occur as a complex in which species of *Fusarium* and *Pythium* predominate. A survey of farms in Runinya near Butare, in southern Rwanda, suggests that root rots have increased in severity over the last four years, with on-farm yield losses estimated at about 60 per cent. While efforts are being made to evaluate entries in an International Bean Root Rot Nursery to identify sources of resistance, research has been directed also at developing cultural methods as a component in an integrated management of root rot. Preliminary results (Table 10) from both on-farm and station trials reveal that organic amendment with *Leucaena* can substantially decrease disease incidence and increase seed yield, and the line RWR 221 was found superior to the local mixture (R.A. Buruchara, unpublished data).

HIGHLIGHTS OF RESEARCH ON BACTERIAL DISEASES

A long and intensive study on halo blight (*Pseudomonas syringae* pv. *phaseolicola*), conducted as a collaborative study between

Horticultural Research International, Wellesbourne in the UK and CIAT since 1985, has led to halo blight probably being better known than any other bean disease in Africa. For many years, the halo blight pathogen was considered to exist as two races, distinguished by their reactions on Red Mexican. More recently, isolates with different reaction patterns on other genotypes have been reported from various places, including Kenya (Stoetzer et al., 1984), Malawi (Msuku, 1985) and Tanzania (Gondwe, 1990). Following further collection, nine races are now distinguished, based on their reactions on eight differential genotypes, and of these, races 3, 4, 5 and 8 are apparently restricted to Africa. Tests of F2 populations of crosses among seven differential cultivars against the nine races, the interaction between races and host genotypes may be explained in terms of a gene-for-gene relationship involving five matching gene pairs (Table 11). The resistance genes R1, R2 and R4 are dominant and R5 is recessive. R3, which is also dominant, appears to be duplicated at different loci. There is evidence that R3 is identical with the dominant I gene that confers hypersensitive resistance to BCMV (Teverson, 1991).

Studies on the epidemiology of halo blight have identified new hosts, including the African native species *Neonotonia wightii* which is thought to be a perennial host (Mabagala and Saettler, 1992a).

Work on common bacterial blight (CBB) in Uganda has led to the development of a model with which to estimate economic loss, as mentioned above. Studies of variation in pathogenicity of isolates of *Xanthomonas campestris* pv. *phaseoli* (Xcp) and its fuscous variant have tended to confirm that the interaction between this pathogen and *P. vulgaris* is quantitative in nature. Conversely, it appears that certain genotypes of *P. acutifolius* differentiate races within Xcp (A.F. Opio, unpublished data), having important implications for resistance breeding, I believe.

HIGHLIGHTS OF RESEARCH ON VIRUS DISEASES

During the past few years, rather extensive surveys have been conducted throughout eastern and southern Africa, with the purpose of determining the geographical distribution and economic importance of viruses naturally infecting beans in our region. Results from these surveys, conducted in conjunction with national virologists and pathologists principally by Mink, Vetten, Walkey and Spence have been partially reported elsewhere (Mink, 1985; Mink and Keswani, 1987; Vetten and Allen, 1989; Spence and Walkey, 1991). The essential findings are that bean common mosaic virus (BCMV) is much the most common and important virus of the common bean in Africa; and that cowpea mild mottle carlavirus (CMMV) is widespread in beans, but is seldom damaging. An exception is the Sudan where CMMV apparently causes a leaf curl that is regarded as the major disease of the crop (El Fahr, personal communication).

Peanut mottle potyvirus and cucumber mosaic cucumovirus are also found in mixed infections in south-central Africa, and bean yellow mosaic potyvirus has occasionally been found in Kenya.

Of paramount importance is the finding that necrotic strains of BCMV predominate over non-necrotic strains in all areas of Africa surveyed, with the notable and unexplained exception of Ethiopia. This has meant that all bean germplasm possessing hypersensitive resistance to BCMV conferred by the I gene is liable to the lethal necrosis 'black root'. Although good progress has been made toward protecting the I gene by the incorporation of recessive genes into agronomically useful backgrounds (Mukoko et al, 1992), susceptibility to black root remains a major hazard in the release of new cultivars with the I gene unprotected. This problem constitutes the central challenge to the leaders of regional sub-projects on BCMV.

Useful progress has also been made in our understanding of the epidemiology of BCMV in Africa. On the one hand, alternate legume hosts have been identified (Spence and Walkey, 1992) and, on the other, we now have greater knowledge of the species of aphids that either colonize or pass through the bean crop (Sohati et al., 1990).

HIGHLIGHTS OF RESEARCH ON NEMATODES

Research from a nematode sub-project run from northern Tanzania have shown that the following nematode genera are associated with the common bean in Tanzania : *Meloidogyne, Aphelenchoides, Tylenchus, Trichodorus, Ditylenchus, Helicotylenchus, Pratylenchus, Hemicycliophora* and *Aphelenchus*. Beans are identified as an alternate host for the main nematode species associated with coffee and banana, with which beans are commonly intercropped, and nematode numbers were significantly higher in association with beans than they were with their original host, banana (Cuthbert, 1990).

Root knot nematodes were found on beans at all sites sampled in the Usambara Mountains, and at 62 per cent of sites in Kilimanjaro and Arusha. Heavy root parasitism by *Meloidogyne* without galling was found at 37 per cent of the sites in the Usambaras and at 38 per cent of the sites in Arusha. A new *Meloidogyne* species was associated with non-gall formation. *Meloidogyne* species parasitic on *P. vulgaris* identified include *M. incognita, M. hapla* and four new species. Selecting for resistance therefore should not be confined to the four polyphagous species. Of the 50 bean lines examined in the field, 19 had less than 10 per cent galling of their root system. When the 8 lines with the lowest scores in the field were tested in pots against a new species of *Meloidogyne* that gave highest galling rates, P 285 and RKSPS 3-16 showed high degrees of resistance, and Masai Red showed some resistance

(Cuthbert, 1990).

Limited studies have also been conducted in Kenya where 17 among 47 lines of bean were found to possess moderate resistance to *M. incognita* and *M. javanica* (Kanyagia, 1990).

COMPONENTS OF AN INTEGRATED DISEASE MANAGEMENT

Various studies have been made of the efficacy of certain fungicides in controlling diseases in beans, but rather few have examined the cost-effectiveness of such chemical application. What is clear is that chemical control of disease in food beans is virtually unknown, because of the scarcity of agro-chemicals, farmers' limited access to equipment with which to apply pesticides, and the meager capital available to small-holders for buying them (Allen et al., 1989). Whereas the adoption of fungicides by the small scale producer of food beans in Africa remains remote, the production of snap beans, in which quality is at a premium, relies substantially on fungicides for disease control, to a point at which residues would seem to constitute a potential problem in discerning markets overseas.

The extent to which fungicides have a role in on-farm bean seed production seems not to have been clarified, although there is evidence (Trutmann and Kayitare, 1991) that disease control and the use of small multiplication plots can help to improve seed quality, decrease disease severity and increase yield on-farm in Rwanda. Cultural practices currently employed by bean farmers do seem to limit disease severity and spread. Recent studies have shown that roguing of diseased seedlings and removal of diseased basal leaves at weeding can decrease disease incidence, and the selection of unblemished seed by farmers is also likely to lessen disease levels in the subsequent crop (Allen et al., 1989).

Various studies have been made of the effect of intercropping with cereals on the severity of bean diseases, as reviewed recently (Allen, 1990). Whereas it is generally found that intercropping affords some protection from disease, this is not invariably so, as shown recently in the case of halo blight (Mabagala and Saettler, 1992b), and it seems that more studies are required to elucidate the factors that underlie such effects, if crop associations are to be harnessed in effective disease management. Perhaps of greater potential is the manipulation of varietal mixtures to protect against disease spread. Mention has already been made of Pyndji and Trutmann's (1988) study on angular leaf spot. Similarly, Davis and Panse (1987) have prodoced evidence that the maintenance of genetic diversity of traditional mixtures of bean varieties contributes to protection against rust, a conclusion also drawn by Msuku and Kapalamula (1989), who constituted artificial mixtures in Malawi. More recently, Mwalyego (1992b) has found that the incidence and severity of anthracnose was significantly decreased in synthetic mixtures, as shown in Table 12. Together, these studies confirm that there is potential for disease protection in mixtures, but they have not yet fully addressed the question of how much protection is afforded by maintenance of traditional mixtures by small scale farmers. The latter is now under investigation in a special project in Tanzania led by Dr. D. Teverson.

Among the disease control strategies available, host plant resistance has become widely recognized as the pivot of integrated disease management, to which both chemical and cultural control measures may contribute. Resistant cultivars cost the farmer nothing, nor does their adoption necessarily disrupt his, or her, farming system (Allen et al., 1989). But what progress is being made in that direction ? Although sources of resistance to most of the major diseases are now available, it is probably true to say that insufficient use has been of them in improving locally adapted and acceptable cultivars. A range of international nurseries of resistant materials have been tested across locations, and some promising materials are being identified as potential parents in breeding (Table 13), but materials often proceed through the sequence of breeding trials possessing substantial susceptibility to many diseases, indicating the need for more effective links between pathologists and plant breeders. Opportunities for improving the evaluation of disease resistance in breeding material are indicated by more appropriate choice of screening site, by the use of artificial inoculation of breeding trial entries in separate screening nurseries, and by the appropriate use of susceptible spreader cultivars (Mushi et al., 1989). Screening for combined resistance to a range of diseases in a given environment has received inadequate attention, despite useful progress in Zambia (Table 14).

FUTURE NEEDS

From the above, I believe it is clear that solid progress has been made over the last few years in Africa. But some gaps remain. There is scope for some basic work on the biology of diseases like scab (*Elsinoe phaseoli*) and floury leaf spot (*Mycovellosiella phaseoli*), both of which are surprisingly ill-known. More attention needs to be given also to genetic analysis of host-parasite interactions in diseases like ALS, so as to better assess the nature and extent of variability in the pathogen. Such studies would be good PhD topics, perhaps. There is obvious need for more expeditious exchanges of resistant germplasm between programmes for more effective field screening. Germplasm exchange is obviously hampered by archaic legislation governing plant quarantine, and there is an urgent need to publish a checklist of the pathogens known to attack the common bean in Africa, so that legislation may be updated on a sound basis, to expedite movement in a responsible manner. Screening procedures are known but insufficiently adopted and more training courses on methods seem warranted, following that conducted in Butare in 1991. Similarly, "hot spots" as sites for screening have been proposed (see Smithson, 1989) : our growing knowledge of the distribution of pathogens and their races needs to be applied to site selection on a Pan-African basis. There is also need for the assembly and distribution of a nursery, like the Pan African Disease Nursery now in preparation, to assist exchanges of the most useful materials as parents in resistance breeding programmes, and to provide a standard set of genotypes wherein site effects can supplement other studies in indicating the existence of race variation.

Farmer awareness of diseases, and the capacity of extensionists to reach those farmers, might be expected to increase through the availability of a good, colour illustrated field manual which is long awaited. Better collaboration between plant pathologists, on-farm researchers, extensionists and the farmer should improve the relevance of pathology research, and better planning at the national level will ensure that research is well-targeted. At the regional level, it is crucial that network research really does fit together into a regional action plan that addresses the highest priority problems, and that peer review among pathologists ensures that only good quality science is supported by the network. I hope that CIAT retains a capacity in bean pathology in Africa to back-stop the regional network in the longer term. Between us, we have set priorities at planning workshops and working group meetings, and we have formulated "Strategies for the nineties" (see Pathology Group Discussion, pp. 638-641 in CIAT African Workshop Series No. 12). Let us now put these plans into good effect, for the benefit of the small scale producer of food beans in this Continent !

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Table 1. Regional Collaborative Research Sub-projects in pathology in Southern Africa, 1987-92.

Topic	Lead Scientist	Lead Institution	Period
ALS	Msuku	Bunda College (MW)	1987-90
ANT	Haciwa	Univ. Zambia (ZA)	1991-
CBB	Mabagala	SUA (TZ)	1992-
BCMV	Lana	SUA (TZ)	1990-
Nematodes	Cuthbert	Min. Agric. (TZ)	1989-90

Table 2. Academic Scholarships, Eastern and Southern Africa

Topic	Scholar	Degree	Period
BCMV breeding	Mukoko (ZW)	PhD Cantab.	1989-92
CBB epidem.	Opio (UG)	PhD SUA	1989-93
CBB breeding	Musaana (UG)	PhD Dar es Salaam	1990-
BCMV epidem.	Sengooba (UG)	PhD SUA	1991-94
Rust epidem.	Habtu (ET)	PhD Wageningen	1989-94
ASCO breeding	Male-Kayiwa (UG)	PhD Dar es Salaam	1990-

Table 3. Special projects cooperating with the network

Topic	Institution	Donor	Period
Halo blight	HRI-Wellesbourne	ODA	1985-91
BCMV	HRI-Wellesbourne	ODA	1989-92
Other viruses	Braunschweig	BMZ	1987-90
Disease in mixtures	NRI/Wellesbourne	ODA	1992-
Anthracnose*	Univ. Paris	EEC	1993-

* Formative stage only.

Table 4. Pan African Workshops*, working group meetings and training courses in bean pathology, 1987-1992.

Topic	Venue	Date	Proceedings
Pathology W/shop	Kigali (RW)	Nov 87	Publ (No. 20)
Legume virus W/gp	Kampala (UG)	Jan 90	Publ (No. 13)
Anth W/gp	Addis Ababa (ET)	Jan 91	Publ (No. 15)
Inoc. methods course	Butare (RW)	Sept 91	-
Fungal pathogens W/gp	Thika (KE)	Jun 92	Publ (No. 23)
BCMV network meeting	Nairobi (KE)	Oct 92	-

* Regional multidisciplinary workshops excepted.

Table 5. The importance of varietal characteristics, according to 120 farmers interviewed in Ruhengeri, Rwanda, 1985-86.

Importance	Characteristic	Score (0-100)
High	Yield	92
	Rain tolerance	85
	Earliness	78
	Drought tolerance	76
Medium	Taste	60
	Upright architecture	48
Low	Storability	36
	Fast cooking	31
	Green bean quality	29
	Leaf quality	20
	Colour	6

Source : J. Voss and K. Dessert, unpublished data.

Table 6. Setting regional priorities among constrains to bean production in southern Africa : the place of diseases.

Identified problem	Rank
Lack of seed	1
Lack of improved cultivars	2
Anthracnose	3
Angular leaf spot (ALS)	4
Bean stem maggot (*Ophiomyia*)	5
Drought	6
Soil acidity	7
Soil infertility	8
Rust	9
Bean beetle (*Ootheca*)	10
Low nodulation	11
Bruchids	12
Common bacterial blight (CBB)	13
Low purchasing power	14
Lack of inputs	15
Pricing policy	16
Land shortage	17
Poor crop management	18
Poor consumer acceptability	19
Bean common mosaic (BCMV)	20

Source : Proceedings of a Regional Participative Planning Workshop, Mangochi, Malawi, March 1991.

Table 7. Reaction of 15 isolates of *C. lindemuthianum* on 12 differential cultivars.

Diff. Cult.	Isolates														
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
Mich-elite	R	R	R	-	S	S	-	S	R	R	R	R	R	S	R
MDRK*	S	S	S	S	S	S	S	S	S	R	S	R	R	S	R
Perry Marrow	S	S	R	-	S	-	S	R	S	R	S	R	S	-	S
Cornell 49-242	R	S	S	S	S	S	S	S	S	R	R	R	S	S	S
Widusa	R	S	S	R	S	R	R	S	R	R	S	R	S	S	S
Kaboon	R	S	S	S	S	S	R	R	R	R	S	R	S	S	R
Mexico 222	S	-	-	S	R	S	R	R	R	R	R	R	-	R	R
PI 207262	S	S	R	R	R	S	R	S	S	R	S	R	R	R	R
TO	S	S	S	S	R	R	S	S	S	R	R	R	S	S	R
TU	R	S	S	S	S	S	S	R	S	R	S	R	R	S	S
AB 136	S	R	R	R	R	S	R	R	S	R	-	R	R	R	R
G 2333	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
No.Cvs attack-ed	6	8	6	6	7	8	5	6	7	0	6	0	5	7	4

* MDRK = Michigan Dark Red Kidney

Source : F. Mwalyego (1992).

Table 8. Effect of adding a resistant component to a varietal mixture on ALS severity and seed yield.

% res. in mixture	Severity (% surface area, at R8-R9)	Yield (kg/ha)
0	14.0 a	609 b
25	3.0 b	658 ab
75	1.5 b	777 a
100	1.5 b	753 a

Source : Pyndji and Trutmann (1988).

Table 9. Reactions (mean scores, 1-9 scale) to white mould in a white mould nursery, northern Tanzania, 1990-91.

	1990 Lyamungu	1991 Lambo	1991 Lyamungu		
		68	61	71	80 DAP*
International WM Nursery :					
XPBV 155	2.5	3.0	2.0	4.0	5.5
NY 5223	2.3	5.5	2.5	4.0	4.0
PL 169787	1.8	3.0	3.5	4.5	4.5
2558	4.8	4.0	3.5	4.5	5.5
MO 162	3.5	3.5	3.5	5.0	5.5
Ex Rico	5.3	2.0	2.0	3.5	4.5
Rabia de Gato	2.0	2.0	1.0	2.0	2.0
Laureat	3.0	5.0	2.5	3.0	3.5
A 55	2.5	1.5	2.0	1.0	1.0
Promising lines :					
CAL 71	2.5	1.0	1.5	1.5	2.0
BAT 1290	2.8	3.0	1.0	1.5	1.5
DRK 2	2.3	2.0	2.0	2.5	2.5
Horsehead x Montcalm	4.3	1.0	2.0	2.5	4.0
AFR 91	1.0	3.0	1.0	2.5	3.0
REC 6	2.3	2.5	2.0	2.5	3.0
SUG 10	2.3	3.0	1.0	1.5	2.0
Horsehead x Malawi	1.8	2.0	1.5	3.0	3.5
Local entries :					
Lyamungu 85	3.8	2.0	3.0	5.0	5.5
Lyamungu 90 (G 5621)	1.8	2.5	3.5	5.0	6.0
Kiburu	3.5	1.0	1.0	1.5	2.5
Most susceptible entries :					
G 13831	5.5	9.0	5.5	7.5	9.0
GLP x 1131	7.0	8.5	6.0	7.5	8.5
Trial Mean	3.5	3.6	2.7	4.1	5.0
S.E	0.16	1.20	0.59	0.77	0.91
C.V. %	45.4	47.5	31.1	26.2	26.0

* DAP : Days after planting. Source : Msuya et al., 1992.

Table 10. Effects of principal paired treatments of organic amendment, raised bed and variety on yield and disease severity in on-station trials (91 A and 91 B seasons).

Factor	Paired treatment	Yield (kg/ha)		Dis.severity[z]	
		91A	91B	91A	91B
Org-amendment[u]	- OA	2056	1663	21.7**	17.5**
	+ OA	2756**	2079**	15.3	10.9
Raised beds[x]	-RB	2414	1756	20.0	14.8
	+RB	2373	1973	17.0	13.6
Variety[y]	LM	1600	1855	26.2**	17.1**
	RWR 221	3186**	1877	10.8	11.3
Mean		2398	1867	18.5	14.2
CV%		25.8	20.3	26.4	20.3

[u] -OA = no organic amendment; + OA + leucaena green manure added 2 weeks before planting (20t/ha).

[x] -RB = no raised bed; RB = raised beds approximately 1 m wide and 30 cm high.

[y] LM = local mixture; RWR 221 (tolerant variety)

[z] Disease severity as % hypocotyl and root tissues covered with lesions

* = paired treatment means are significantly different (p = 0.05) by ANOVA

** = paired treatment means are significantly different (p = 0.01) by ANOVA

Source : R.A. Buruchara, unpublished data 1991.

Table 11. Gene-for-gene relationships between *Phaseolus* differentials and races of *Pseudomonas syringae* pv. *phaseolicola*.

Differential cultivars	Resist. genes	1	2,5	3	2,3	1,2,4	6	1,2	5	1,5
Canadian Wonder		+	+	+	+	+	+	+	+	+
A 52 (ZAA 54)	4	+	+	+	+	-	+	+	+	+
Tendergreen	3	+	+	-	-	+	+	+	+	+
Red Mexican UI3	1,4	-	+	+	+	-	+	-	+	-
1072	2	+	-	+	-	-	+	-	+	+
A 53 (ZAA 55)	3,4	+	+	-	-	-	+	+	+	+
A 43 (ZAA 12)	2,3,4,5	+	-	-	-	-	+	-	-	-
Guatemala 196-B	3,4	-	+	-	-	-	+	-	+	-

Source : Teverson (1991).

Table 12. Effect of varying proportions of a resistant and susceptible cultivar in a synthetic two component bean mixture on anthracnose severity.

% resistance in mixture	Severity 4	8	12 WAE
0	4.3	5.7	7.5
25	4.7	5.8	6.5
50	3.0	3.7	5.5
75	2.0	3.3	5.0
100	1.0	1.0	1.0

Adapted from Mwalyego, 1992b

Table 13. Reactions (mean scores, 1-9 scale) to angular leaf spot of lines selected from BALSIT, Arusha, 1991.

Entry	Reactions (days after sowing) 55	63	78
Most susceptible entry	4.5	5.0	7.0
Least susceptible entries*	1.0	1.0	1.0
Selected entries :			
AFR 241	3.5	4.5	7.0
G 4738	2.0	1.8	1.7
LB 110	2.0	3.5	4.5
SUG 21	2.5	3.0	3.0
Uyole 84	4.0	4.0	5.0
Trial mean	1.7	2.0	2.4
SE +/-	0.31	0.29	0.45
CV %	25.4	20.2	26.2

* DOR 372, V 79099, RJR 22, G 5473, G 5207, XAN 97, G 2858
A 300, A 690, EMP 81, LB 718-1, LB 809-3, LB 512-2

Table 14. Reactions (mean scores, 1-9 scale) of bean genotypes with combined resistance to ALS, anthracnose and ascochyta blight in Mbala, Zambia, 1986-89.

Entry	1986-87			1987-88			1988-89			Yield
	ALS	ANT	AB	ALS	ANT	AB	ALS	ANT	AB	kg/ha
G 6040	2.0	3.5	2.0	3.5	2.0	2.0	3.0	1.5	3.0	1817
G 1098-1C-1C	3.0	2.5	2.0	1.5	1.0	3.0	3.5	2.5	4.0	1217
BAT 1510	2.0	3.0	2.5	2.5	2.0	3.5	2.5	3.0	5.5	1105
997-CH-73	3.0	4.0	3.5	2.0	3.0	2.5	2.0	1.5	5.0	1060
Carioca	2.5	3.0	4.5	2.0	1.0	3.5	3.0	1.0	5.5	963
Mbala Local	5.0	2.5	3.0	1.5	2.0	3.5	4.5	3.0	8.0	436
Susc. check	6.0	6.5	5.5	6.0	7.5	5.5	7.0	7.5	9.0	
Mean	3.2	3.7	3.0	2.9	2.3	3.2	3.3	2.6	5.1	
CV%	30	27	26	40	53	21	23	43	19	
SE	0.7	0.7	0.6	0.8	0.9	0.5	0.5	0.8	0.7	

Adapted from Kannaiyan, 1989.

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

"PLUS ONE" TRIALS

"MINUS ONE" TRIALS

Source: Graf and Trutmann (1987)

DISCUSSION OF THE PATHOLOGY PAPERS IN THE CROP PROTECTION SESSION

Edje : Sohati found that aphid numbers were higher when plant population was low. Is this an effect of size of plant from wider spacing ?

Allen : No, it's related principally to an alighting response of aphids.

Edje : Is *Myzus persicae* the same as occurs on tobacco ?

Sohati : Yes.

Teri : Did you look at the whole field ?

Sohati : No, a sample of 1 m was taken, and transferred to a per hectare basis.

Allen : Different aphid species have been identified; we now need to find which are vectors of BCMV, and whether different aphids differentially transmit different strains of BCMV.

Ampofo : Data show numbers of aphids per infested plant, and not aphids per plant. Is that true ?

Sohati : Yes.

Edje : Is it easy to distinguish between BCMV transmitted by seed and by aphid ?

Sohati : Yes, symptoms from seed-borne infection develop earlier than those transmitted by aphids.

Teri : Could it be possible that different strains of BCMV are different viruses ?

Lana : Yes, there is a proposal that necrotic strains should be assigned to a distinct virus.

Allen : It may be that necrotic strains are regarded as belonging to bean necrotic mosaic virus in future, but we should appreciate this may have consequences beyond the realm of science.

Aggarwal : What is the status of material combining different characters ?

Mukoko : I have to self it for one further generation to stabilize the characters. I hope then to maintain the characters combined in one variety.

Allen : These materials will have considerable value, in view of I-gene materials currently being released.

Bosch : I don't follow the I-gene story. I understand there are better combinations with the I-gene. Is there any problem in releasing I-gene materials ?

Mukoko : If a necrotic strain is present, it will kill the whole crop, whereas a mosaic susceptible variety will survive.

Kuhn : I-gene materials are being released, but they are not being wiped out in Swaziland.

Allen : The history of the use of the I-gene is that it has proved most valuable where there is no necrotic strain. It worked in the Americas, but when this germplasm was introduced into Africa, because of different strains, it caused problems. Now we are trying to solve these problems.

Mushi : What should breeders do with materials containing the I-gene unprotected ?

Aggarwal : The risk is there, but it is less on farmers' fields.

Youngquist : It is a calculated risk.

Lupwayi : What strains are present in America ? Can ELISA differentiate between necrotic strains ?

Mukoko : Yes, but if you don't have specific antisera it will be difficult.

Mkandawire : Why was Mukoko's first planting so much affected by BCMV ?

Mukoko : Not early planted but early inoculated.

Arias : Can I get a list of entries which carry I-gene ?

Mukoko : Yes.

Arias : Our seed company is importing Carioca, and I am worried. Is it possible to give advice to the Government of Mozambique ?

: is there any relationship between BCMV and cowpea aphid- borne mosaic ? That also worries me.

Allen : Carioca contains the I-gene, but cannot carry BCMV through its seed. It is dangerous, and it would be good to list materials which are protected.

: Cowpea aphid-borne mosaic virus looks similar, and is a closely related potyvirus, but the chances of one infecting the other host are remote.

Mkandawire : Can the I-gene in Carioca be protected ?

Mukoko : Yes, by incorporating the bc-3 and bc 2-2 genes.

Youngquist : The I-gene also gives resistance to halo blight race 3. There is a value in keeping the I-gene.

: Is there any competition between strains that we are sure are not present in certain areas, like NL-3 in Ethiopia ?

Lana : No. People are trying to trace the evolution of certain viruses.

Edje : What happened to using disease specimens instead of pictures to increase farmers' awareness, as proposed in work at Sokoine University of Agriculture ?

Teri : Nothing was done. These suggestions are still valid.

Lupwayi : How was Table 6 (priorities) in Allen's paper put together ?

Mkandawire : In 1991, national coordinators met in Malawi and set these priorities during a participatory planning workshop.

Bosch : Soils seem not well represented in those priorities.

Allen : Soil scientists were represented, and soil problems were thoroughly analyzed.

Mkandawire : How much interaction exists among sub-projects in pathology ?

Allen : Inadequately as yet, but the recent fungal pathogens working group meeting in Thika was a step in that direction.

SESSION 5 : PLANT IMPROVEMENT

PROGRESS IN BREEDING FOR RESISTANCE TO BEAN STEM MAGGOT IN COMMON BEAN

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ABSTRACT

A breeding programme was initiated in February 1991, to develop bean cultivars resistant to bean stem maggot (BSM). Lines ZPv 292 and Ikinimba, earlier reconfirmed to have high levels of resistance to BSM, were crossed to susceptible but adapted cultivars, Lyamungu 85, Canadian Wonder and Dore de Kirundo. Crosses were advanced to F2 and F3 generations with F2 remnant seed kept for field evaluation. Seeds of the F2 and F3 crosses were sown at Selian Agricultural Research Institute after the 1992 Masika rains, at a time when beanfly populations were determined to be very high. Fifty entries comprising of the crosses, parents and checks were sown in a RCB design replicated three times. Data indicated that there were significant differences among crosses for percent cumulative mortality, mortality caused by bean stem maggot, and number of black pupae per plant. The F2 and F3 crosses performed similarly suggesting that additive gene action is largely responsible for resistance. The two resistant parents appeared to differ slightly in both specific and general combining abilities. Ikinimba tends to combine better than ZPv 292. However, the appropriate statistical genetic analyses need to be carried out to support the above statements.

PROGRESS IN BRUCHID RESISTANCE BREEDING

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ABSTRACT

The bruchids, Zabrotes subfasciatus (Boh.) and Acanthoscelides obtectus (Say), are the two most important species on stored bean in the world, causing reduction in seed weight, quality and viability. Chemical control for bruchids is effective, but too expensive for some small-scale farmers. Sometimes, the chemicals are not available when needed. Other control measures, such as using wood ash, combining ash, sand, sunning and plant extracts, are cumbersome and time consuming. Genetic resistance to bruchids could be a cheap and easy way to control these pests. Breeding work has been initiated at Sokoine University of Agriculture to incorporate the arcelin gene which confers resistance to Z. subfasciatus in bean lines adapted to Tanzanian conditions. Lines with arcelin protein genes were obtained from CIAT. Several crosses have been made. The F1 seed will be backcrossed three times to the adapted parents then selfed before they are screened for bruchid resistance. Bean lines adapted to Zimbabwe, Uganda and Ethiopia will also be used in crosses.

INTRODUCTION

The bruchids, *Zabrotes subfasciatus* (Boh.) and *Acanthoscelides obtectus* (Say) are the two most important pests of stored beans in the world, causing a reduction in seed weight, quality and viability. However, research on bruchids in the SADC region has been rather limited and the losses they cause to small scale farmers' storage have not been quantified. In East Africa, losses were estimated to be between 30 and 70% (Karel and Autrique, 1989). van Schoonhoven and Cardona (1980) estimated that up to 85% of the bean crop in Mexico, Central America and Panama, and from 7 to 15% in Brazil, are lost to bruchids.

Numerous measures have been used to control bruchids. Farmers frequently mix wood ash, cow-dung ash, inert dusts, vegetable oil, plant extracts and frequent sunning to reduce insect infestation.

Chemicals are costly and may be toxic to man. Some means of biological control would obviously better suit the needs and practices of small-scale farmers.

Following a report by Janzen et al. (1976) that phytohemagglutinin in black beans possessed insecticidal action for certain bruchids, Osborn et al. (1986) associated arcelin in wild bean seeds with their resistance to bruchids. Genetic analysis revealed the presence of arcelin to be controlled by multiple alleles designated Arc^1, Arc^2, Arc^3 and Arc^4. Some of these sources of resistance have now been successfully transferred to cultivated backgrounds.

Cardona et al. (1990) found bean seed and pellets of bean seed meal containing arcelin 1 to completely inhibit feeding of *Z. subfasciatus*, and that of *A. obtectus* slightly. Feeding trials on rodents have demonstrated no deleterious effect of cooked beans containing arcelin (Cardona, personal communication).

Bruchid entomology and bean storage research have the potential for improving food security in SADC, where small scale farmers face common problems. A regional collaborative research sub-project on bruchids was initiated, with support from the SADC/CIAT regional bean programme. This collaboration involves researchers from Zimbabwe (University of Zimbabwe and Department of Research and Specialist Services) and Selian Agricultural Research Institute. There is also a collaboration with researchers in other countries in the exchange of information and germplasm (eg. CIAT, Ethiopia, Uganda and Burundi).

The objectives of the bruchid sub-project in SADC have been stated by Giga et al. (1990). Sokoine University of Agriculture (SUA) has taken responsibility of breeding for bruchid resistance.

MATERIALS AND METHODS

Bean lines with arcelin protein were obtained from CIAT, Cali, Colombia. These are lines which are also improved in other characteristics, and were used as donors of arcelin genes. Five adapted and improved lines from SUA have been used in initial crosses. Improved bean lines from other programmes will also be used.

Crosses were done in the screenhouse at SUA. The F1 seeds have been harvested. These will be backcrossed to the adapted parents or selfed to get F2 seeds on which insect feeding trials will be done to identify lines with arcelin protein. These lines will then be backcrossed to the adapted parents in three backcrosses. Then the BC3F2 lines will be evaluated in the field for other agronomic characteristics and selection will be made for the best lines.

RESULTS

The crosses which have been made are presented in Table 1.

DISCUSSION

This paper presents progress made so far. More crosses will be done using other RAZ lines, and more improved adapted lines from different bean research programmes will be used in the crosses, so as to create populations with wide genetic diversity.

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Table 1. Crosses and the number of F1 seed obtained

Cross		Number of F1 seed harvested
C11-1/216-2-6-2	x RAZ 24-2	21
C11-2/216-7-8	x RAZ 24-2	20
EP 4-4	x RAZ 24-2	14
EP 3-2	x RAZ 24-2	12
SUA 90	x RAZ 24-2	16

BREEDING APPROACH AND PROGRESS MADE IN THE SADC/CIAT BEAN PROGRAM IN MALAWI

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ABSTRACT

The SADC/CIAT bean program to serve the more southern latitudes started in 1991 in Malawi with the arrival of a bean breeder. A large number of germplasm lines introduced from CIAT, Colombia and from the national programs in the region were evaluated at Bunda and Dedza for disease resistance, general adaptation and yield. A wide variation in yield and resistance to diseases was observed. Promising lines have been selected for inclusion in a zonal nursery to be sent to participating national programs in the 1992-93 crop season. A program to screen germplasm for tolerance to Al toxicity was initiated at the Lunyangwa research station in Malawi.Aluminium toxicity was modified in field trials by adjusting soil pH with lime. A contrasting response to varying levels of acidity was observed. Crosses have been initiated to improve the locally adapted varieties for resistance to diseases, high yield and tolerance to Al toxicity. Several regional activities were undertaken that included a zonal yield trial distributed to seven countries, a breeders' travelling workshop, and visits to several countries in the region to interact with other national programs.

INTRODUCTION

The SADC/CIAT bean program started in 1987 with four staff positions based in Arusha, Tanzania. They were a breeder, an agronomist, an entomologist and a plant pathologist/coordinator. A fifth staff member, a breeder, to service the more southern latitudes of the project member states, arrived on post at Bunda College of Agriculture, Malawi in July, 1991. The activities and results being reported in this paper relate to the one crop season of 1991-92.

Beans are an important grain legume crop in almost all the member countries of the project except Botswana and Namibia. Among these, Tanzania, Malawi, Mozambique and Angola are considered to be the major bean growing countries (Grisley, 1990). Beans in most parts of the SADC region are grown either as a pure crop or as an inter-or relay crop, depending upon the length of growing season and the type of cropping system practised by farmers. Varieties grown vary from pure lines to complex mixtures. In Malawi, for example, beans grown in the north comprise as much as 15-20 components; such mixture is well-liked for home consumption. Whereas less complex mixtures, or pure lines, are grown in the south for commercial purposes (Bean Research Report, 1992). The main production constraints are diseases, insect pests, low soil fertility, drought, lack of high yielding varieties and seeds. Considering these constraints and other responsibilities of the program, the following have been established as the main objectives.

Objectives

1. to identify and develop improved bean germplasm in collaboration with national programs in the region, with CIAT's regional programs in Africa and at CIAT headquarters.

Main constraints include diseases such as angular leaf spot (ALS), common bacterial blight (CBB), rust, bean common mosaic virus (BCMV) and halo blight (HB); low P and Al toxicity; drought stress; bean fly; seed characters and low yield. The CIAT program in Malawi will concentrate on ALS, CBB, low soil fertility and drought, and will interact with other CIAT breeding programs on the remaining constraints.

2. to strengthen national programs by providing technical back-stopping; exchanging germplasm and information; participating in training, workshops and seed issues; and establishing a regional network.

3. to liaise with governmental and non-governmental organisations to promote project activities and awareness.

4. to administer project activities in Malawi.

Breeding approach

The major emphasis in the program is to conduct strategic research in collaboration with national programs on problems that are of regional importance, such as low soil fertility, drought, disease and insect pests, and to develop suitable materials to overcome these problems. In addition, introduction of promising germplasm from CIAT and other parts of Africa, initiated this year, will continue. Efforts are being initially directed to dwarf plant types. Climbers will be included once the program reaches greater maturity.

The breeding strategy involves initial testing of materials, either developed locally or introduced, at representative sites in Malawi. Selections from these will be made available to national programs, in the form of a zonal nursery or as a specific trial for further testing in their own environments, to select lines that will meet national needs and criteria. The CIAT breeder will help any national program to evaluate any type of breeding materials either received through the regional program, developed locally or introduced from any other place.

PROGRESS REPORT

The activities of 1991-92 were divided into two main categories:

a) Research activities

b) Regional activities

The results of these activities, and the environmental conditions under which various trials were grown, are described below:

Research activities

Most of the research activities in 1991-92 related to evaluating introduced and local germplasm for disease resistance, yield and general adaptation, except at Lunyangwa where the material was evaluated for tolerance to acidic soil conditions. In addition crosses were initiated to improve locally adapted materials, especially for disease resistance and higher yield potential. Results obtained are summarised below:

Climate and soils

Trials were planted at three sites representing different rainfall, disease spectra, soil conditions, altitudes and latitudes. Sites selected were Bunda College, the Dedza Hills and the Lunyangwa Research Station near Mzuzu. All these sites receive rainfall in a unimodal pattern, the season extending from November to April.

Bunda and Lunyangwa are mid-altitude locations, but temperatures at Lunyangwa are relatively cooler due to its being surrounded by mountains and receiving higher rainfall. This results in the presence of some of the cool season diseases, such as anthracnose and halo blight. The other important diseases present at these locations are ALS, BCMV, and rust. In addition, due to relatively higher temperatures, CBB is usually present at Bunda. Dedza Hills is a high altitude location where anthracnose, halo blight, ALS, rust, BCMV and scab are the main diseases.

The soils at Lunyangwa are acidic (high Al, low P) as compared to the other two locations, but such soils are also common in several areas of the Dedza Hills.

Climatic data during the crop season at these locations are given in Table 1. The year was very dry, particularly in February and, to some extent also in March. This resulted in severe drought conditions in most parts of the country not only reducing yields but also affecting the pressure of disease. For example, CBB was more prevalent in the high altitude locations and halo blight incidence in Dedza was delayed until intensity of rains increased and temperatures became cooler in March. Results of the 1991-92 crop season should be interpreted keeping these environmental factors in mind.

Germplasm evaluation

Every year, the bean team at CIAT headquarters in Colombia forms a bean team nursery called the VEF (Viveros del equipo de frijol). A sub-set of this nursery, based on dwarf plant type (1 and 2a), medium to large seed and disease resistance, was imported into Malawi. This represented a total of 166 lines from VEF 1989 and 150 from VEF 1990. Additionally, 197 dwarf germplasm lines from Malawi, 37 farmers' varieties from the southern highlands of Tanzania, 12 local collections and selected lines from Zambia (from previously introduced material from CIAT), and three recommended varieties from Zimbabwe, were obtained.

These materials were planted at Bunda College, both with and without a disease spreader, and in the Dedza Hills with a disease spreader. The disease spreader at Bunda was the variety Nasaka, whereas in Dedza Hills it was Phalombe. Both these varieties are highly susceptible to major bean diseases. The idea of planting a disease spreader was to create enough disease pressure for different diseases present at the two sites, while growing beans without a spreader was to evaluate them under more natural conditions, allowing for a comparison of performance under different disease pressures.

The field design was an unreplicated single test row plot, four meters long separated from other rows by 0.75m when evaluated without a spreader row. In the case of testing with spreader rows, the susceptible variety was planted in a continuous row about two weeks before planting the test rows, and each spreader row was followed by two test rows four meters long. Distance between all the rows was 0.75m. Data were recorded on flowering, diseases and yield. The range and means of important characters recorded are shown in Table 2.

It should be noted that this was the first time that a large number of lines from the Malawi germplasm collection was grown alongside a large number of introduced materials. This provided an opportunity to compare these materials, and to assess the potential of an enlarged genetic base that could accelerate selection of better genotypes, both as varieties and as parental materials. The performance of a few of the
top yielders in various germplasm categories evaluated at Bunda (with and without a disease spreader) and at Dedza (with a disease spreader) is given in Tables 3, 4 and 5, respectively. In general, yields were low at Bunda, because of drought. They were further reduced when the materials were tested with a disease spreader when disease incidence was high, indicating the important effect of disease on yield. In spite of having been planted with a susceptible spreader, yields at Dedza were higher than those at Bunda, probably because of a better rainfall distribution and cooler temperatures. Comparing the yields between different groups of germplasm, the two VEFs registered generally higher yields, indicating the presence of better yielding entries in these nurseries. Among the top 20 entries in the two VEFs, a large number of them carried the code 'AFR', indicating advanced lines produced at CIAT headquarters for Africa. Yields were comparatively low in the Malawi germplasm, perhaps attributable to higher disease incidence and less vigorous growth. In spite of lower yields, most of the Malawi germplasm has excellent seed characteristics and is earlier in maturity. These are important traits and should be kept in mind while developing superior varieties. Looking at the frequency of entries among the top 20 yielders in different sets of germplasm, nine of them were common only to the VEF 89 at the two Bunda sites. In other cases, common entries varied from two to five. Overall, only CAL 113 and AFR 520 (in VEF 89), AND 920 (in VEF 90), Sumbawanga Market 18 (in Tanzanian germplasm) and EMP 255 (from Zambian germplasm) were common among the top 20 at the three sites. Otherwise, ranking of entries based on yield, was

quite different in all three tests, suggesting a strong genotype and environment interaction.

Looking at disease resistance, some lines, particularly those bearing the LSA code in VEF 89, showed resistance to ALS, but most of them produced low yields due to poor adaptation. In the same VEF, two lines, MCM 5006 and MCM 5007, had low ALS incidence, but again were poor yielders. These lines will be further evaluated, and if they continue to maintain high levels of resistance, they will be used in the hybridization program. Promising selections from these nurseries, based on yield and disease resistance, have been selected as parents for crosses and inclusion in a Zonal Nursery to be distributed this year.

Disease nurseries

Five disease nurseries, the IBCMBRN (International Bean Common Mosaic and Black Root Nursery), IBRN (International Bean Rust Nursery), VIB (Vivero Internacional de Bacteriosis, the CBB Nursery), IBAT (International Bean Anthracnose Trial) and BALSIT (Bean Angular Leaf Spot International Trial) from CIAT, and the PADN (Pan African Disease Nursery) from the African region, were introduced and tested in Malawi. There were a total of 64 entries in the IBCMBRN and two sets of it were planted, one at Bunda without a disease spreader, and the other at Dedza with a disease spreader. The IBRN (59 entries), VIB (55) and BALSIT (17) were planted both at Bunda and Dedza, but because of seed shortage, the IBAT (39) was planted only at Bunda. The PADN, which had 64 (49+15 checks) entries and was replicated twice, was planted both at Bunda and Dedza. All these nurseries were planted with a disease spreader. Evaluation of these nurseries was done as described above, except that the planting was delayed at Dedza. Late planting at Dedza caused a high incidence of black root, which either killed the crop or reduced its yields. In the IBCMBRN, where the majority of entries were of MCM or MCR (multiple recessive genes) origin, the yields were not affected by black root, and were generally higher. Yields in other nurseries at Dedza were lower than those at Bunda, because of the presence of a large number of I-gene lines. Data from a few top yielding varieties in these nurseries are given in Tables 6 and 7. Four lines, (MCR 4003, MCR 2514, MCM 2202 and MCM 1020), included in the IBCMBRN, that produced high yields and had low levels of disease incidence are currently being crossed to incorporate disease resistance into recommended varieties grown in Malawi (eg. Nasaka, Phalombe, Canadian Wonder and Sapelekedwa).
In addition, two lines (H2 Mulathino and A 588), from the IBAT showed high levels of resistance to ALS and rust and were high yielding at Bunda. Since this nursery was not planted at Dedza, their reaction to black root is not known. They will be further

evaluated next year.

Screening for tolerance to aluminium toxicity

In many parts of bean growing areas in Southern Africa, soils are highly acidic (pH 4.0 to 5.0), resulting in low availability of P and high Al toxicity that adversely affect both plant growth and grain yield. This problem is quite widespread and the best way to overcome it is to identify varieties that can be successfully grown under these conditions. With that objective in mind, a program to screen bean varieties on acid soils was initiated at two sites, at Lunyangwa in Malawi and at Misamfu in northern Zambia. Both these locations represent typical low pH areas. This work is being carried out in close cooperation with the Adaptive Research Planning Team in northern Zambia and with Dr. S.K. Mughogho, the soil scientist at Bunda College of Agriculture in Malawi.

The trial consisted of 57 varieties out of which 14 came from CIAT headquarters in Colombia, 11 from CIAT's regional program in Uganda, one from Malawi used as a local check, and the remainder from northern Zambia. These varieties represent both dwarf and climbing plant types. The lines from CIAT's programs have been screened previously for their tolerance to acid soils but those from Zambia, which are local collections from the Mbala-Kasama area, had not been so evaluated before. The local check from Malawi, 2-10, was selected for its adaptation and high yields in the Lunyangwa area. The experiment at both the sites was established on a piece of land that had been kept fallow for several years. Soil samples were taken prior to planting to determine the pH and status of other nutrients, particularly of P and Ca. Details of the soil analysis from Misamfu, where the trial was lost due to poor management, are not available, but at Lunyangwa, where the trial was a success, the soil was found to have very low P and Ca levels and 1.38 me/100g soil acidity contributing to 81% acidity (Al+H) saturation. Lime, in the form of calcium carbonate, was used to neutralize acidity, and a fertility gradient was established in the field where acidity was neutralized at saturation levels of 0, 25, 50, 75 and 100 per cent, respectively. For example, at 100% saturation level, it was expected that the acidity would have been completely neutralized. The varieties were planted in single row plots across the five gradients where it was possible to readily observe their performance. Due to limited quantity of seed, only one replication was planted. Nevertheless, the results obtained were dramatic and varieties showed great variation in their response to the different levels of acidity established.

Among the 57 varieties, one line did not germinate. Yields of a few of the remaining 56 varieties, separated into two groups of dwarfs and climbers and showing a contrasting performance, are given in Table 8 and in Figures 1 and 2. Among the dwarf varieties, Carioca and Rio Tibaji, showed a positive response in yield when acidity was reduced with each increased application of lime. Conversely varieties like A 283 and Kabulangeti BO-117-1 (a local Zambian line) were more stable in their yields across the five gradients. A 283, perhaps the most tolerant variety, produced the highest yield under high levels of acidity. Among the climbing varieties, Chilemba Mukulu B 0038 (from Zambia), was the highest yielder at the highest Al level, showing it to be also tolerant to high acidity. These results indicate the existence of genetic variability in beans for tolerance to high acid soils, or to Al toxicity.

Hybridization

A series of crosses between locally adapted varieties, (Nasaka, Canadian Wonder, Phalombe, Sapelekedwa and ZPV 906), and those identified from the CIAT germplasm for their resistance to diseases and high yields (MCR 4003, MCR 2514, MCM 2202, MCM 1020, CAL 113, AFR 499, AFR 520, AFR 596 and AFR 563), have been initiated to combine adaptation and good seed characters of the locally grown materials with disease resistance and high yield. Crosses have also been initiated between these varieties and the apparently Al tolerant lines, Pintado, G 5059 and Calima. The total number of crosses currently underway is about 50. More will be initiated when all the data are fully compiled and additional promising parents are identified.

Regional activities

The main regional activities carried out during the past year were as follows.

Zonal Trial

A long planned zonal trial designated as SAZBYT (Southern Africa Zonal Bean Yield Trial) was finally organized and sent out to participating countries. This trial was the result of a recommendation made at the Workshop on Bean Varietal Improvement in Africa, held at Maseru, Lesotho from January 30- February 2, 1989 (Smithson and Gridley, 1990).

The main objectives were to exchange elite germplasm among national programs, monitor reaction of different diseases and pests and identify superior genotypes. The trial contained 14 entries contributed by Lesotho (3), Malawi (4), Tanzania (3), Zimbabwe (3) and a local check. Names and origin of these varieties are given in Table 9. The field design was a randomized complete block, with four replications. The plot size was 4 rows, 4m long with a distance of 50cm between rows and 10cm between plants within the rows. Ten sets of this trial were sent to seven countries: Lesotho (2), Malawi (1), Namibia (1), Swaziland (1), Tanzania (2), Zambia (2) and Zimbabwe (1). At the time of writing, results have been received only from Zambia and Zimbabwe. The trial in Swaziland was reported to have failed due to drought. Data from other countries are awaited. Yields from Zambia and Zimbabwe are reported in Table 9. Because of drought, they were generally low. It is assumed that Uyole 84 failed to germinate at both sites. So far, RAB 303 appears to have been the most promising in Zimbabwe. When more data become available, a better picture of performance of varieties included in this trial will appear.

Breeders travelling workshop

A breeders travelling workshop was organised for the period March 7-13, 1992, to visit the SADC/CIAT program in Malawi and the activities of the national programs in Malawi, Zambia and Zimbabwe. Participants were CIAT's bean breeders based in Colombia, Malawi, Tanzania and Uganda; a bean breeder from the CRSP program based at the University of California, Davis, USA; and two national bean breeders from Tanzania and one each from Zambia and Malawi. Breeders were also invited from Angola, Namibia and Mozambique, but they were unable to participate. The team, however, was joined by a bean breeder and an agronomist from the national program in Zimbabwe when the group visited that country. The original plan was to visit Malawi, Zambia and Zimbabwe, but due to early harvest hastened by drought in Zambia, that country was not visited. The group, therefore, visited only Malawi and Zimbabwe. Nonetheless, the workshop was considered to have been highly successful as it provided a rare opportunity of bringing together a large number of experienced breeders who could see the breeding materials in the field and discuss among themselves the future needs and activities of the region. One of the highlights of the visit was that, in Malawi, the participants were able to see and evaluate the newly introduced materials from CIAT headquarters in Colombia, grown side by side with the germplasm received from the national programs in Malawi, Tanzania, Zambia and Zimbabwe. It exhibited a wide range of genetic diversity, and selections made from this material will be included in a Zonal Trial to be distributed next season.

Visits to National Programs

One of the important activities of the project are to strengthen national programs by visiting them and discussing with the NARS scientists their technical and logistic needs, developing collaborative research projects and helping them to evaluate research materials. To accomplish these objectives and to get acquainted with different national programs, visits were made within Malawi and to Angola, Tanzania, Zambia and Zimbabwe. During these visits, discussions were held with the national scientists working on beans and various field trials visited. In some countries, particularly Zambia and Zimbabwe, visits were made more than once.

Visits to other regional programs

Two visits were made to the Great Lakes regional program, once in June 1991 during the CIAT Africa staff meeting, and a second time in June 1992. During both the visits, research activities of the national, as well as of the CIAT's regional program were visited, and discussions held on future collaboration. The immediate result of these visits has been that several promising lines adapted to poor soils have been introduced to the SADC region for further testing, and the national program in Malawi has received a set of climbing beans.

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Table 1. Rainfall and temperature means during the growing season at three sites in Malawi where bean trials were conducted in 1991-92.

Parameter	Sites		
	Bunda	Dedza	Lunyangwa
Latitude (°S)	13.58	14.20	11.27
Altitude (mamsl)	1060	1630	1125
Rainfall (mm)			
Nov	250.0	194.9	130.1
Dec	188.1	269.6	126.5
Jan	176.2	210.4	229.6
Feb	22.3	66.8	59.8
Mar	116.4	83.8	94.0
Apr	6.1	43.8	63.6
Temperature (°C)			
Nov - min	17.0	15.8	19.5
max	28.5	24.9	27.4
Dec - min	16.9	15.2	18.1
max	27.3	23.2	25.0
Jan - min	17.7	16.3	18.2
max	27.5	22.9	25.6
Feb - min	17.3	16.6	18.5
max	29.2	25.5	26.8
Mar - min	16.6	16.1	18.5
max	26.9	24.4	25.9
Apr - min	15.5	14.6	17.7
max	28.2	24.0	25.0

Table 2: Range and means of important characters recorded on varieties included in germplasm evaluations planted at Bunda and Dedza, 1991-92.

Location and Trial	No of Entries	Characters													
		DFF		ALS (1-9)		CBB (1-9)		HB (1-9)		BCMV (1-9)		Rust (1-9)		Yield (g/plot)	
		Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean
Bunda with spreader															
VEF 89	166	38-56	44	2-7	4	1-4	2	-	-	1-5	3	1-7	3	0-246.86	74.70
VEF 90	150	38-57	43	2-7	4	2-5	3	-	-	2-5	4	1-7	4	0-183.18	65.72
Germplasm:															
MW	197	38-49	41	2-7	4	2-5	3	-	-	3-7	5	2-6	5	0-198.75	49.10
TZ	37	40-56	45	3-5	4	3-5	3	-	-	4-6	5	2-5	4	0-93.56	20.32
ZA	12	38-48	43	2-5	3	3-4	3		-	4-5	5	2-5	4	8.4-155.72	71.00
ZW	3	40-48	45	2-3	2	3-4	4	-	-	4-5	5	2-3	3	4.16-88.45	33.60
Bunda without spreader															
VEF 89	166	33-52	42	1-5	3	-	-	-	-	2-5	3	1-8	4	0-286.99	109.29
VEF 90	150	20-51	39	2-4	3	-	-	-	-	3-4	3	2-6	3	0-327.39	142.54
Germplasm:															
MW	197	34-49	39	2-6	4	1-5	4	-	-	3-4	3	-	-	2.26-242.98	112.19
TZ	37	35-42	38	3-5	4	1-3	2	-	-	3-4	3	-	-	8.75-243.99	100.47
ZA	12	35-42	39	3-4	3	1-3	2	-	-	2-3	3	-	-	68.71-244.86	140.40
ZW	3	40-41	41	2-3	3	1-1	1	-	-	3-3	3	-	-	78.99-256.84	179.31
Dedza with spreader															
VEF 89	166	38-49	44	1-6	4	1-4	1	1-5	1	1-8	2	1-7	2	0-343.70	151.97
VEF 90	150	38-49	43	2-5	4	1-4	1	1-5	1	1-7	1	1-7	2	28.99-498.44	214.13
Germplasm:															
MW	197	38-48	40	2-8	4	1-7	4	1-7	2	1-7	4	1-7	3	0-340.52	125.52
TZ	37	34-51	40	3-5	4	1-5	3	1-2	1	1-7	4	1-6	3	0-283.18	128.15
ZA	12	38-53	44	3-4	3	1-5	2	1-4	1	1-3	1	1-5	2	0-265.41	110.34
ZW	3	-	-	1-1	1	1-5	3	1-1	1	1-1	1	1-1	1	0-206.14	90.78

Table 3. Performance of a few top yielders in various germplasm categories planted at Bunda College with a disease spreader 1991/92.

	DFF	Disease Scores (1-9) ALS1	ALS2	BCMV	CBB	RUST	WB	Yield (g/plot)
VEF 89 :								
CAL 113	40	3	3	3	2	4	3	246.86
AFR 520	41	4	6	3	2	4	4	223.58
CAL 116	40	5	6	3	3	3	5	213.97
AFR 522	40	4	6	3	3	4	4	207.01
AFR 524	41	4	6	3	1	3	3	206.81
CAL 114	38	4	3	3	4	5	5	198.10
KID 31	38	4	4	3	3	4	4	196.37
CAL 115	38	3	3	3	3	4	3	164.19
VEF 90 :								
AFR 593	41	4	6	3	3	4	5	183.18
EMP 255	38	3	3	3	3	5	2	179.27
CAL 125	38	4	3	3	3	5	4	172.18
AFR 565	40	4	5	3	3	5	3	167.92
CAL 122	41	5	3	3	3	6	5	163.54
SUG 75	41	4	4	4	2	4	3	160.45
DRK 65	40	4	5	3	3	4	3	160.42
AND 909	40	5	6	3	3	4	3	159.83
Malawi Germplasm :								
968	40	5		5	3	5		198.75
975	41	4		5	3	5		184.54
974	40	5		4	3	5		166.28
533	40	5		6	3	5		150.77
1243	40	4		5	4	5		134.10
1297	40	4		5	3	5		128.27
1283	40	4		5	3	6		127.15
Germplasm from TZ, ZA, ZW :								
ZPV 299	40	4		5	3	5		155.72
ZPV 906	40	4		4	3	5		147.59
EMP 259	40	4		4	3	5		113.16
EMP 255	40	4		4	3	5		97.77
Swanga Market-18	40	4		5	4	3		93.56

Table 3. (Continued)

	DFF	Disease Scores (1-9) ALS1	ALS2	BCMV	CBB	RUST	WB	Yield (g/plot)
Swanga								
Market 37	40	5		5	3	5		88.46
RAB 331	40	3		5	4	3		88.45
Check plot means :								
A 286	47	3		3	3	4		154.08
A 344	47	2		2	1	1		125.99

Note : Dates for recording angular leaf spot, ALS 1 and ALS 2 were 49 and 68 days after planting respectively.
WB = Rhizoctonia web blight
DFF = Days to first flower
CBB = Common bacterial blight

Ed. note : Swanga = Sumbawanga, presumably.

Table 4. Performance of a few top yielders in various germplasm categories planted at Bunda College without a disease spreader in 1991/92.

Entry	Disease scores (1-9)				Yield
	DFF	ALS 1	BCMV	RUST	(g/plot)
VEF 89 :					
AFR 521	36	2	3	4	286.99
AND 873	35	4	3	4	286.83
CAL 113	40	3	3	4	276.49
AFR 520	39	3	3	4	257.51
KID 31	35	4	3	4	256.22
AFR 510	36	3	3	5	250.06
AFR 511	36	3	3	2	249.89
MCM 5006	39	2	3	1	241.91
VEF 90 :					
AFR 573	39	3	3	4	327.39
CAL 127	40	3	3	3	284.00
DRK 62	36	3	3	4	257.70
CAL 121	40	3	3	3	257.69
SUG 74	39	4	3	4	251.80
AND 920	38	3	3	3	251.52
SUG 94	41	3	3	3	249.42
MCR 4003	41	2	3	3	248.46
Malawi Germplasm :					
639	37	4	3	4	242.98
769	37	5	3	3	201.59
582	35	5	3	3	195.98
10-4	36	5	3	3	194.28
786	36	5	3	4	178.11
745	34	5	3	4	172.36
1054-1	36	5	3	3	171.19
Germplasm from TZ, ZA, ZW :					
CAN 31	40	3	3	1	256.84
EMP 84	41	3	3	1	244.88
Swanga Market-18	36	4	4	2	243.99
EMP 255	40	3	3	3	242.00
EMP 242	40	3	3	2	209.16

Table 4. (Continued)

	DFF	Disease scores (1-9)			(g/plot)
		ALS 1	BCMV	RUST	
PAN 125	41	2	3	1	202.10
Mbozi-Mbeya -23	36	4	3	3	198.79
Check plot means :					
A 286	39	2	3	1	321.56
A 344	42	2	3	2	122.69

Table 5. Performance of a few top yielders in various germplasm categories planted with a disease spreader at Dedza Hills in 1991/92.

Entry	DFF	Disease Scores (1-9)						Yield
		ALS1	ALS2	HB	BCMV	RUST	CBB	(g/plot
VEF 89 :								
AFR 490	48	4	4	1	4	1		343.70
AFR 508	38	3	4	3	4	1		338.10
PAI 153	48	5	4	1	7	5		336.84
CAL 117	44	1	4	1	1	1		320.11
AFR 499	44	1	3	1	1	1		319.95
LSA 89	44	1	3	2	1	1		303.73
CIFEM 87036	44	1	4	1	2	7		295.70
SUG 63	44	1	6	1	1	1		288.08
VEF 90 :								
DRK 51	38	4	4	4	1	1		498.44
MCR 4003	48	1	3	1	1	1		483.76
AFR 563	48	1	4	1	1	1		472.01
AFR 576	41	1	4	1	1	4		464.32
MCM 2003	48	1	3	1	1	1		422.08
AFR 599	38	1	4	3	1	1		408.22
AFR 609	40	1	3	1	1	1		377.82
AND 890	38	1	3	1	1	1		368.35
Malawi Germplasm :								
800	40	6	7	3	3	4	2	298.84
1056-1	38	5	dry	1	2	3	4	232.41
632-1	40	4	6	1	4	1	1	198.09
2	38	2	4	1	4	2	2	193.63
1275	38	3	6	1	5	3	3	193.52
997-1	38	5	6	3	4	1	4	186.94
596	44	4	6	1	3	1	5	186.30
Germplasm from TZ, ZA, ZW :								
Swanga Market-10	38	3	3	1	6	1	4	283.18
Swanga Market-4	34	6	5	2	3	1	2	278.61
EMP 255	38	2	4	1	1	2	3	265.41
Swanga Market-2	38	5	5	1	3	3	3	254.22
ZPV 299	38	3	3	1	2	3	3	222.07

Table 5 (Continued)

		Disease Scores (1-9)						
	DFF	ALS1	ALS2	HB	BCMV	RUST	CBB	Yield (g/plot
Kantawa-Swanga-32	38	3	3	1	3	5	3	214.75
Swanga Market-17	40	4	4	1	4	3	3	212.94
Check plot means :								
A 286	45	2	4	1	2	1		48.95
A 344	44	1	4	1	1	1		62.80

Note : Dates for recording ALS 1 and ALS 2 were 51 and 74 days after planting, respectively.

Ed. note : Swanga = Sumbawanga, presumably.

Table 6. Performance of top yielders in various disease nurseries planted at Bunda College in 1991/92.

Entry	Nursery	DFF	Disease Scores (1-9) ALS1	BCMV	CBB	RUST	Yield (g/plot)
MCR 2514	IBCMBRN	41	3	3	3	-	355.21
MCM 5001	IBCMBRN	43	2	3	2	-	351.46
MCM 1015	IBCMBRN	41	2	3	2	-	320.72
BAT 1297	IBCMBRN	41	3	3	2	-	312.57
MCM 1020	IBCMBRN	43	3	3	3	-	311.85
MCR 4003	IBCMBRN	41	2	3	3	-	309.22
MCM 3512	IBCMBRN	43	3	3	1	-	296.21
Redlands GreenleafB	IBCMBRN	36	3	3	1	-	288.85
MCM 2005	IBCMBRN	42	3	3	1	-	278.34
MCM 2002	IBCMBRN	41	3	3	4	-	266.00
AND 378	BALSIT	41	2	4	4	4	213.51
A 690	BALSIT	42	1	3	3	1	192.68
MITA 235-1-1-1-M	VIB	40	2	4	3	1	307.98
A 716	VIB	40	2	4	3	1	297.77
MECOSTA	VIB	39	5	4	2	5	215.91
A 253	VIB	40	2	4	2	1	215.17
A 377	VIB	47	2	4	3	1	207.48
GLP-X-1136	VIB	41	2	4	4	2	204.34
A 585	IBAT	49	2	3	2	1	246.44
H2 Mulat-inho	IBAT	39	1	2	2	1	244.43
A 588	IBAT	41	1	3	4	1	183.67
A 742	IBRN	40	2	3	3	1	193.93
AFR 396	IBRN	40	2	3	3	4	184.48
XPB 155	PADN	42	1	-	5	1	231.20
EX RICO	PADN	42	1	-	3	1	214.90
BAT 36	PADN	43	3	-	4	1	210.60
A 140	PADN	42	1	-	4	1	206.30
XAN 78	PADN	43	2	-	4	1	193.60
Check plot means :							
A 286	IBAT	40	1	4	3	1	368.37
A 344	IBAT	41	1	3	3	1	308.41

Table 7. Performance of top yielders in various disease nurseries planted at Dedza Hills in 1991/92.

Entry	Nursery	DFF	Disease Scores (1-9) ALS1	ALS2	HB	BCMV	CBB	RUST	Yield (g/plot)
MCM 2202	IBCMBRN	48	1	3	1	1	6	1	579.01
MCM 2201	IBCMBRN	48	1	3	1	1	5	6	413.14
MCM 1020	IBCMBRN	48	1	3	1	1	2	1	407.42
MCM 1019	IBCMBRN	44	1	3	1	1	5	3	386.99
MCR 4003	IBCMBRN	38	1	3	1	1	2	3	385.98
MCR 2514	IBCMBRN	38	4	5	2	1	4	1	383.65
MCM 5003	IBCMBRN	40	1	3	1	1	4	1	380.74
MCM 1014	IBCMBRN	38	1	3	1	1	1	3	380.64
MCR 4002	IBCMBRN	44	2	4	1	2	1	4	345.54
CAL 85	IBCMBRN	48	4	5	1	1	2	1	340.99
G 2858	BALSIT	41	2	-	-	6	4	3	166.32
IAPARBAC 14	VIB	46	3	-	-	1	3	1	275.02
JULES	VIB	46	6	-	-	4	7	2	187.02
SUG 37	VIB	41	5	-	-	2	3	2	153.78
MITA 235-1-1-1-M	VIB	43	2	-	-	2	3	2	137.22
PF (G 18844)	VIB	41	2	-	-	2	3	2	126.30
GORDO	VIB	46	5	-	-	4	5	4	125.38
ZAA 44	IBRN	41	2	-	-	3	4	2	190.31
BAT 1427	IBRN	41	2	-	-	2	6	2	172.26
Redlands Greenleaf B	IBRN	41	5	-	-	3	5	2	158.64
AND 349	IBRN	46	3	-	-	5	2	1	128.90
SUG 28	IBRN	43	4	-	-	4	4	4	127.21
MCM 1015	PADN	45	-	-	-	-	-	-	346.88
CAL 85	PADN	43	-	-	-	-	-	-	163.38
BLACK DESSIE	PADN	43	-	-	-	-	-	-	138.29
MCR 4004	PADN	42	-	-	-	-	-	-	130.94
PI 169787	PADN	38	-	-	-	-	-	-	125.94

Table 7 (Continued)

		Disease Scores (1-9)						Yield
	DFF	ALS1	ALS2	HB	BCMV	CBB	RUST	(g/plot)
Check plot means :								
RAB 303	38	2	3	1	1	2	1	282.78
A 286	44	3	3	1	2	1	1	108.38

Note : Dates for recording ALS1 and ALS2 were 53 and 69 days after planting, respectively.

Table 8. Response of some of the dwarf and climbing bean germplasm evaluated for tolerance to aluminium toxicity at Lunyangwa, Malawi, in 1991/92.

Identity	Seed yield (g/plot) per saturation level (%)					
	Control	25	50	75	100	Totals
1. DWARFS :						
CIAT Introd.						
Calima	58.50	51.48	62.42	89.99	62.85	325.24
Pintado	61.73	92.16	99.32	72.38	67.41	393.00
G 5059	95.07	58.18	96.07	100.72	59.32	409.36
BAT 477	22.83	29.38	62.44	117.75	140.73	373.13
Carioca	50.85	88.75	180.47	243.06	268.39	831.52
A 283	100.67	153.27	148.60	90.56	90.03	583.13
Rio Tibaji	83.14	93.70	164.32	205.01	208.00	754.17
Local Germplasm, Zambia						
Kabulangeti BO 117-1	72.16	97.88	92.06	99.22	63.53	424.85
Kabulangeti BO 117-2	21.96	54.82	49.82	55.72	64.16	246.48
Sankana B 0020-3	17.79	50.27	104.60	149.35	138.03	460.04
Samwikala B 0049-1	31.02	38.33	30.14	38.32	80.77	218.58
Matoli B 0078-1	33.77	16.83	19.29	71.44	247.96	389.29
Matoli B 0078-2	40.97	22.68	51.22	57.03	89.68	261.58
Ngwangwa B 0104-3	58.39	55.32	97.24	55.85	56.76	323.56
Masai Red B 0128-1	48.83	27.83	96.56	117.04	75.32	365.58
Mbala Local 3	25.81	0.00	21.28	55.72	59.96	162.77
2. CLIMBERS :						
CIAT Introd.						
G 11401	15.17	13.26	46.01	81.35	53.02	208.81
G 19113	32.52	84.58	28.38	26.99	36.84	209.31
G 19439	24.45	35.56	24.59	43.17	60.42	188.19

Table 8. (Continued)

Identity	Seed yield (g/plot) per saturation level (%)					
	Control	25	50	75	100	Totals
Local Germplasm, Zambia						
Kabulangeti BO 117-3	99.63	28.48	50.34	27.65	67.66	273.76
Sankana B 0020-2	50.93	61.22	142.68	163.64	151.20	569.67
Sankana B 0020-5	44.42	47.77	123.36	145.50	217.30	578.35
Chilemba Mukulu B 0038-1	103.14	84.53	62.73	104.30	62.05	416.75
Check plot :						
2-10	52.17	66.07	65.16	87.35	73.68	344.43

Ed. note : Kabulangeti is also sometimes spelt Kablanketi.

Table 9. Yields of entries in the Southern Africa Zonal Bean Yield Trial (SAZBYT) in Zambia and Zimbabwe in 1991/92.

Entry	Source	Seed Yield (kg/ha)	
		Msekera Zambia	Harare Zimbabwe
BAT 477	Malawi	283	144
A 344	Malawi	339	225
Nasaka	Malawi	276	244
A 286	Malawi	248	444
RAB 303	Zimbabwe	136	825
Puebla 152 Cafe	Zimbabwe	98	156
Carioca	Zimbabwe	318	275
Uyole 84	Tanzania	0	0
Uyole 90	Tanzania	206	481
Kabanima	Tanzania	108	0
SSB	Lesotho	216	42
NW 590	Lesotho	186	198
SWH	Lesotho	246	569
Local Control			
Red Canadian Wonder	Zimbabwe	-	66
ZPV 292	Zambia	252	-
Trial Mean		208	305
CV %		32.3	58.4
SE		67.2	82.3

Figure 1: Response of selected dwarf bean varieties to soil acidity.
(Lunyangwa, Malawi, 1991/92)

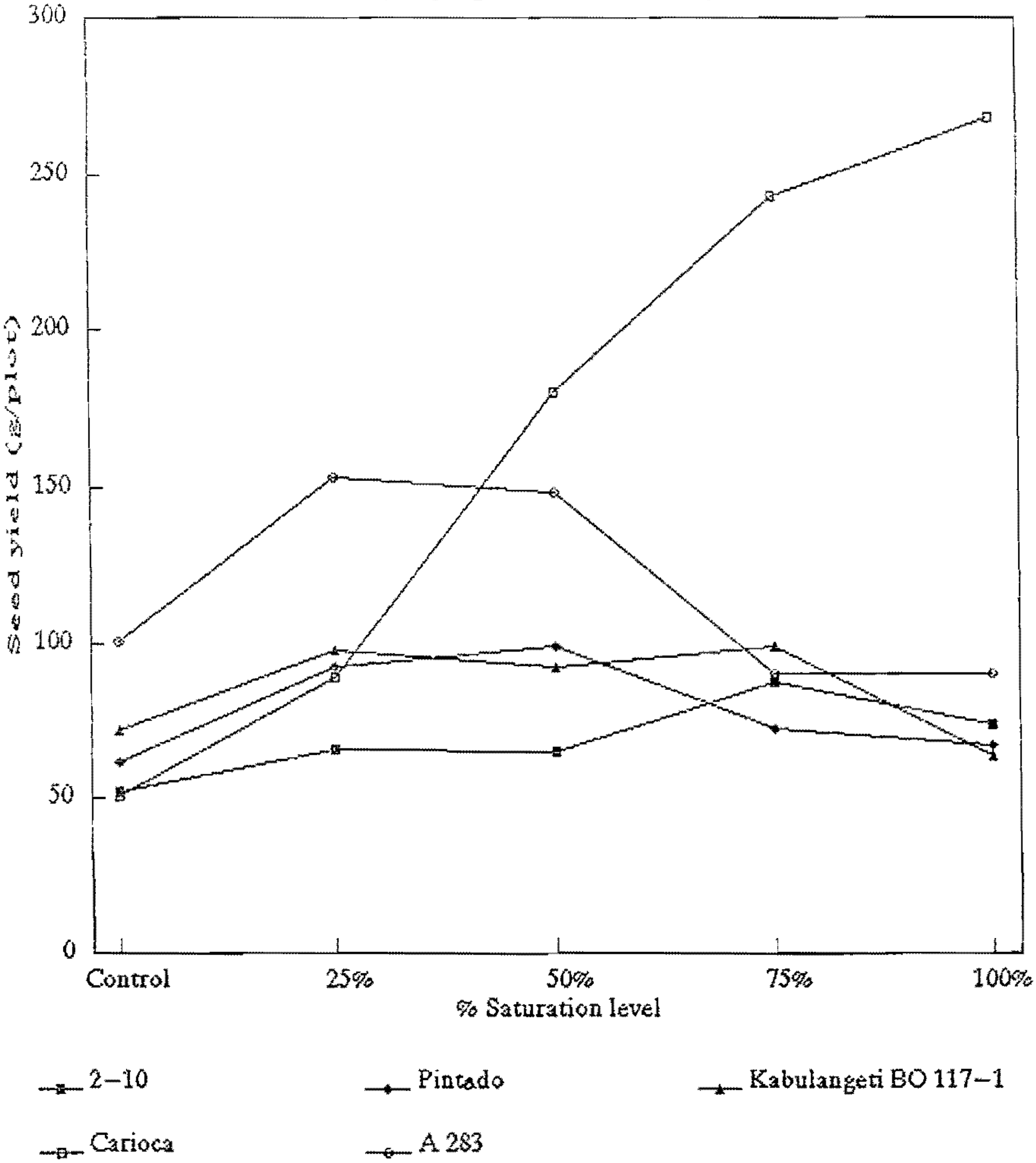
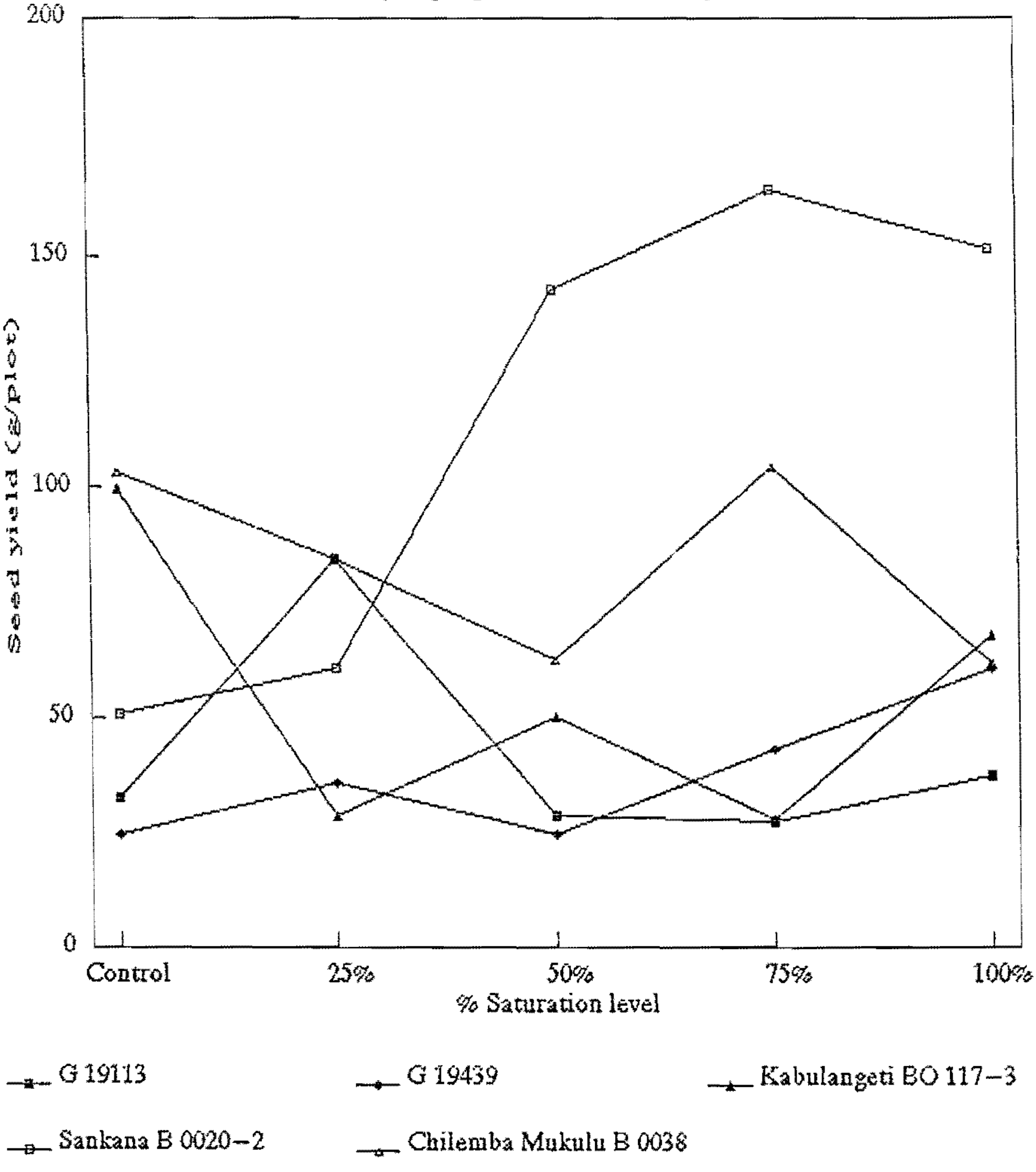


Figure 2: Response of selected climber bean varieties to soil acidity.
(Lunyangwa, Malawi, 1991/92)



NEW PERSPECTIVES IN BEAN BREEDING IN ARUSHA AS PART OF THE SADC/CIAT REGIONAL BEAN PROGRAM

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ABSTRACT

The needs in bean breeding are undergoing constant evolution as new varieties come on the market and the needs of our farmers change. However, there are many problems which seem always to be with us and old solutions and methodologies still represent the best tactics. There are two main areas that the bean breeder in Arusha will be addressing. These are germplasm supply and scientific development. Germplasm can come from anywhere in the world and CIAT will try and facilitate its movement. National program scientists should have good access to all germplasm. The second area covers how the germplasm is evaluated. Proper trial designs need to be used, correct analysis of the data is imperative, proper assessment of the conclusions need to be made and a plan developed to implement the conclusions.

INTRODUCTION

Agricultural research is under constant evolution. As plant breeders, we are agents of change in directed evolution. Our goals of today are not the same as those of a few years ago, nor can we expect them to be the same in the future. The needs of our clientele will change, the disease and insect pests will evolve to effectively counter genetic resistances, and farming methods will change. In fact, most of what we do must be viewed as of temporary value. This is not to diminish its importance, but rather to instill appreciation for the dynamic and complex nature of the problems that we are facing. We need breeding methodologies that are flexible enough to meet the problems as they evolve.

All agricultural research has as an ultimate goal the development of materials, or methodology, that will enhance the productivity of farmers. Consequently, it is important to have an appreciation of the farm and a full understanding of the environment in which the bean varieties being developed will be grown. This can only be done through visits to farms during the cropping year. Farmers must be consulted as to their needs and constraints in terms of crop production. More specifically, plant breeders need to predict what the constraints will be five to ten years into the future, when today's research will become available at the farm level.

The SADC/CIAT bean breeding program in Arusha has to be able to respond to changing needs in the region, as much as national programs have to be able to adopt to changing needs within each country. CiAT has always been a source of bean germplasm to enhance genetic variability within bean breeding programs. This will continue in the future. However, CiAT's role in the international research community is changing. More emphasis is being placed on back-stopping research, and less on the development of finished products. This is a shift in emphasis that is shared among all the CGIAR centers. Practically speaking, this is going to result in a greater need for on the spot research activities in the SADC region. Consequently, I see my role as SADC/CiAT regional breeder as addressing two broad areas: Germplasm Enhancement and Scientific Development.

In germplasm enhancement, we are here to facilitate the interchange of germplasm from CiAT in Cali, Colombia, from the three CiAT Regional bean programs in Africa, and from the national programs. This material can be from the VEF (Viveros de Equipo Frijol = bean team nursery), IBYAN (International Bean Yield and Adaptation Nursery), AFBYAN (African Bean Yield and Adaptation Nursery), regional trials and nurseries, the various disease nurseries, specific crosses made in Cali or elsewhere, and germplasm developed as a part of sub-projects. In Arusha, I am developing three crossing nurseries. The first one is crossing nine lines that have exhibited some tolerance to bean stem maggot (BSM). This is being done in conjunction with the regional entomologist and the sub-project on BSM. A second nursery is crossing material with known disease and insect tolerances, or tolerance of low soil fertility with the intent of developing lines with multiple tolerances. The third nursery will be addressing the need of improving particular market classes. There are various estimates (from 20% to 80%) of beans being produced by small holders as being marketed commercially. By improving on these cultivars (e.g., with a particular disease resistance), there will be a ready seed distribution scheme whereby improved seed will be available to the farmer through market channels.

Scientific development is a rather broad term meant to cover the whole range of activities that enhance the productivity of a research scientist. This starts with proper training for those areas that need improvement, consultation on specific problems, and the effective communication of research findings to a wider audience. We need to examine our current methodologies and ask questions about why we are conducting our research as we are. Are we following tried and tested methodologies that were set up for solving problems that are outside of our mandate? Methodologies that are very practical when sufficient resources are at hand may be counter productive on limited budgets. Why plant trials at twelve sites when funds are only sufficient for handling four? Certainly, bad data are worse than no data. Peer review of our programs for the purposes of constructive criticism is both desirable and essential.

Breeding is a numbers game : the more lines for testing, the more test sites available, the more information gathered to improve our chances of finding elite lines. We have to find new ways to gather sufficient information to make informed selections, even in the face of declining budgets. How can we utilize information from farmers in variety development ? There are many varieties available to the farmer and every farmer has their preference. As breeders, we have an obligation to satisfy the needs of our clientele. This implies that we have to be ready to release many differing varieties. We have to accept that, at best, any particular line will not be adopted by more than half of the farmers in any particular area. Yet we need to serve all of the farmers. As a start, we need to identify all of the major market classes and be sure that we have at least one suitable variety for each class for each agro-ecological zone.

As an example of one of the ways of improving our scientific methodology, I want to discuss a problem that I have noticed in analyzing multilocation trials. It has come to my attention that there is a bit of confusion on the proper test of significance for the main effect of entry, and the entry by location interaction. Imagine a trial of 16 entries, grown at six locations, with three replications at each site. Table 1 contains the form of the analysis of variance and the expected mean squares. In this example, replications and locations are random effects. That is, they are chosen as representative of a larger population. The piece of land containing the first replication is representative of any piece of land on which the trial is sited. Similarly, the sites or locations represent any site or location in the region being tested. Replications and locations are considered random effects. The entries, however, were specifically chosen as the ones that were to be tested. As they only represent themselves, and not a larger population, they are a fixed effect. If we were to test these entries on only one farm, then we would be interested in how they perform relative to each other on that farm, from one replication to the next. If they are relatively consistent in order of performance, then we would have a high confidence in selecting the best one. If the order changes greatly from one replication to the next then our confidence would be low in selecting the best entry. Statistically, this is what we do when constructing an F test of the ratio of the entry variance to the error variance. For multilocation trials, we have less interest in how entries perform relative to each other from replication to replication on any one farm, and much more interest in *how they perform relative to each other from one site to the next*. Consequently, it is the variation among entries relative to the variation due to the entry by location interaction that is of major concern in trying to discern if one entry is truly better than the other entries when compared from location to location. This F test is calculated as the ratio of the mean square for entry divided by the mean square for entry by location interaction.

By way of this example, I hope to have illustrated how we can work together to improve our scientific methodology in the region. Ultimately, there are many ways that enhanced communication among all the bean researchers can work for everyone's benefit. We need to stress linkages among farmers, researchers, and the extentionist.

Table 1. Form of the analysis of variance for multilocation trials, where there are six locations (L), three replications (R) and sixteen entries (E).

Source	df	MS	Expected Mean Square	F
L	5			
R(L)	12			
E	15	MS1	$\sigma^2_e + r\sigma^2_{EL} + rl\phi^2_E$	$\frac{MS1}{MS2}$
E x L	75	MS2	$\sigma^2_e + r\sigma^2_{EL}$	$\frac{MS2}{MSe}$
error	162	MSe	σ^2_e	

AFBYAN I, II, III - MAKING HEADWAY IN UNDERSTANDING

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ABSTRACT

The African Bean Yield and Adaptation Nurseries (AFBYANs) were designed to facilitate the distribution of elite lines among the national programs in SADC and to supply information on agro-ecological zones and the lines adapted to them. Twenty five entries have been grown in each of the AFBYAN's (seven entries common to all three) in a total of forty environments. Differences among entries have been detected and the entry by environment interaction is highly significant. In AFBYAN II, Eberhart Russell yield stability parameters were calculated and regression coefficients ranged from 0.56 (Nain de Kyondo, mean yield = 870 kg/ha) to 1.45 (G 12470, mean yield = 1638 kg/ha). Principal components analyses were conducted on the residuals from an analysis of variance on location means. These residuals represent the variation due to the entry by location interaction. The first principal component was found to be highly correlated to latitude of the bean growing environment. This type of analysis permits the quantification of environmental factors that influence genotype performance under different growing conditions.

INTRODUCTION

The African bean yield and adaptation nursery (AFBYAN) was initiated by CIAT staff in Africa, in collaboration with the National Program staff from sixteen countries. This large number of research scientists working together need to be commended for their efforts. It is unlikely that such extensive trials would ever have been possible without the valuable input from each and every participant. This set of trials was designed to contribute to the wide distribution and evaluation of elite germplasm and to contribute information for defining agro-ecological zones in the bean growing areas of Africa (Smithson, 1989; Allen and Smithson, 1991). To date, the trial has been grown at forty two sites since 1987 (Table 1) and is expected to be grown at another twenty in the next two years. This will comprise an extensive data base on the adaptability of this set of bean germplasm in Africa. This report covers some summary data on all three trials and then looks at the

AFBYAN II in terms of yield stability analysis and principal component analysis. The latter analysis gives some insight as to those environmental characteristics that were most important in contributing to the entry by location interaction.

The AFBYAN trials were set up using incomplete block designs to account for variabiltity within the experimental fields. Twenty five entries, grown in four-row plots, four meters long have comprised the basic trial. Seven of the entries are common to each of the three sets of test material. AFBYAN I was grown from 1987 to 1989 and results are reported in full elsewhere (Smithson, 1990; Smithson and Grisley, 1992). AFBYAN II was grown from 1990 to 1991, and AFBYAN III had its first growing season in 1992. Besides the 'usual' agronomic data that were collected, environmental data for each site (rainfall, temperature, solar radiation, altitude, etc.) were included. The environmental data are vitally important to characterize areas of adaptation and efforts need to continue to ensure their collection.

The highest yielding entries from each set of trials are listed in Table 2. It is interesting to note that Ikinimba and G 2816 appear to be consistently high yielding over a large number of sites. The analyses of variance for grain yield (Table 3) indicate that, though the entry by location interactions are significant, there are significant differences among entries, when averaged over all locations (AFBYAN I and II). This is not true in the AFBYAN III, where only four sites have been reported on to date. It should be noted that the test of significance for entry uses the entry by location interaction as its 'error'. For AFBYAN III, where the four test sites in Tanzania were environmentally very different (hot lowlands at Morogoro, cool and drought at Mitalula, good growing conditions at Selian), the lack of significance for entry indicates that none of the entries are significantly better than any of the others. This supports the concept that different varieties will need to be bred for different agro-ecological zones to maximize production.

High mean yield is an important characteristic for varieties, but equally important (especially for limited resource farmers) is how stable a variety is when tested over multiple years or locations. Farmers tend to place emphasis on varieties that do not fail them under adverse conditions. There are a number of stability parameters that can be calculated, usually by re-partitioning the sum of squares for the entry by environment interaction. Those that are used as standards are the Eberhart-Russell (or Finley-Wilkinson stability parameters which look at a regression analysis of varietal mean yields regressed on an environmental index based on entry mean yields (e.g. Eberhart and Russell, 1966). Table 4 shows the regression coefficients and the R square for the entries in AFBYAN II. As originally proposed by Eberhart and Russell, a stable variety would have a high mean yield, a regression coefficient near unity, and low deviations from regression (i.e., a high R square). This was meant to indicate that varieties with these characteristics would behave predictably : that their response to changing conditions would be stable; and that when farmers invested in their crop, the crop would respond favorably, with a good return on investment. Others have argued that for limited resource farmers, a low slope would indicate varieties that performed relatively well under poor growing conditions and thus should be recommended. Certainly, these parameters should be viewed as a 'tool' and their use should be applied correctly to reflect the needs of the farmers. For instance, Ikinimba has a high mean yield and a slope near one which makes it a good choice over a wide range of environments (Fig. 1). For farmers in areas of very good growing conditions, G 2816 has a higher yielding potential, however, it may perform poorly if conditions are unfavorable. Calima, with a low slope, may perform better in the poorest environments, but its overall yield is low and would not be a suitable choice in better environments. These analyses are based on all environments in the AFBYAN II; however, varieties need to be recommended for only a subset of these environments. Therefore, these analyses need to be repeated for each set of environments or recommendation domains.

One of the uses of the AFBYAN's is to try and identify bean growing areas that are similar in terms of reponse of a set of genotypes. A method for doing this is to analyze the entry by location interaction by finding principal components and then relating the principal components to environmental parameters with simple correlations. This will then identify those environmental parameters that contribute most to variance associated with the entry by location interaction. This will indicate along which environmental gradients the locations need to be stratified to limit the magnitude of the interaction. Thus, those locations that are put together, define a recommendation domain and will result in a minimal entry by location interaction. Briefly the method is as follows:

1. Calculate an AOV on entry mean values where the model only includes the main effect of location and entry. The residuals from this analysis form the basis for the principal component analysis.

2. Calculate the principal components from a two dimentional (entry and location) matrix of the residuals. Each location receives a value (score) for each principal component.

3. The principal component scores are then correlated to environmental parameters recorded for each location. The environmental parameters that are most highly correlated to each principal component indicate which parameters are of interest. The first few principal components are likely to be the only ones that account for much of the variation, though the higher order principal components may give some

information as to environmental effects that have an effect on relative variety performance.

4. Locations that have similar principal component scores should be grouped together to minimize the entry by location interaction.

Each of the principal components accounts for a portion of the entry by location interaction. This proportion is given in Table 5 for the first ten. It is readily observed that only the first few components account for any appreciable amount of the entry by location interaction. The correlations between the first five principal components and the environmental parameters that were recorded are listed in Table 6. The first principal component is most highly correlated to day-length. This indicates that beans planted at sites farthest from the equator, or those with planting dates about one month before the summer and winter solstices, differ greatly from those planted near the equator or at the equinoxes. Though principal components analysis is somewhat robust in terms of outliers, it would be worthwhile to recalculate them without the data from Lesotho, which is at the highest latitude. The second and third principal components do not appear to be highly related to the environmental factors that were measured. The fourth principal component is most related to soil type and change in day-length, whereas the fifth is correlated strongly with minimum temperatures. These parameters can now be used to describe sites that should be grouped together which comprise agro-ecological zones.

The AFBYAN's have been found to be useful for exchanging elite bean germplasm. Their use for describing agro-ecological zones is now coming to the forefront and should be valuable in locating an efficient number of test sites for variety testing in the national programs.

ACKNOWLEDGEMENT

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Table 1. AFBYAN data sets received from participating countries.

Country	AFBYAN I	AFBYAN II	AFBYAN III
Burundi		1	1
Ethiopia	1	4	1
Kenya		1	1
Lesotho		3	1
Madagascar	1	1	1
Malawi			1
Mozambique		2	1
Namibia		1	1
Sudan		1	1
Swaziland		2	1
Tanzania	2	3	4
Rwanda		1	1
Uganda	3	1	2
Zaire			
Zambia	3		1
Zimbabwe			1
Total	10	21	19

Table 2. Highest yielding entries - AFBYAN I, II, & III, (kg/ha) with number of reporting sites in parentheses.

AFBYAN I (12)		AFBYAN II (24)		AFBYAN III (4)	
Ikinimba	1738	G 2816	1731	PEF 14	2284
Carioca	1710	G 12470	1638	Ikinimba	2071
XAN 76	1705	Ikinimba	1632	CAL 32	1975
G 2816	1659	HF56463-1	1621	Kilyumukwe	1777
G 13671	1557	XAN 76	1593	MCM 5001	1764
Rubona 5	1522	A 176	1564	GLP 1004	1760
Urubono.	1504	997-XH-173	1509	A 321	1709
Std. Err.	168		142		305

Table 3. Analyses of variance for grain yield (kg/ha) from AFBYAN I, II, & III.

	I		II		III	
Source	df.	MS	df.	MS	df.	MS
Entry	24	1.52*	24	2.97*	24	0.52
Ent x Loc	239	0.34*	552	0.48*	72	0.37*
error	598	0.12	1152	0.11	158	0.21

* significant at P=0.01

Table 4. Eberhart-Russell or Finley-Wilkinson stability parameters for AFBYAN II for grain yield (kg/ha).

Entry	Mean Yield	Slope (b)	R square
Nain de Kyondo	870	0.56	0.76
Ubusogera 6	1392	1.14	0.80
997-XH-173	1524	1.01	0.82
HF-56463-1	1591	1.34	0.89
INIA 10	1196	0.76	0.87
A197	1087	0.81	0.82
A 410	1484	1.11	0.82
G 12470	1638	1.45	0.85
INIA 12	1200	0.95	0.83
A 176	1526	1.06	0.86
Calima	1134	0.67	0.79
Carioca	1203	0.83	0.86
GL 1004	1421	0.84	0.84
Red Wolaita	1297	1.10	0.91
Ikinimba	1644	1.06	0.83
K20	1163	0.79	0.75
A 370	1354	1.11	0.93
Kilyumukwe	1425	0.97	0.86
GLP 24	1504	1.28	0.88
ZPV 292	1373	0.87	0.88
Ex-Rico	1351	0.89	0.67
GLPX 92	1467	0.96	0.76
G 2816	1722	1.33	0.85
G 13671	1140	0.86	0.85
XAN 76	1580	1.19	0.93

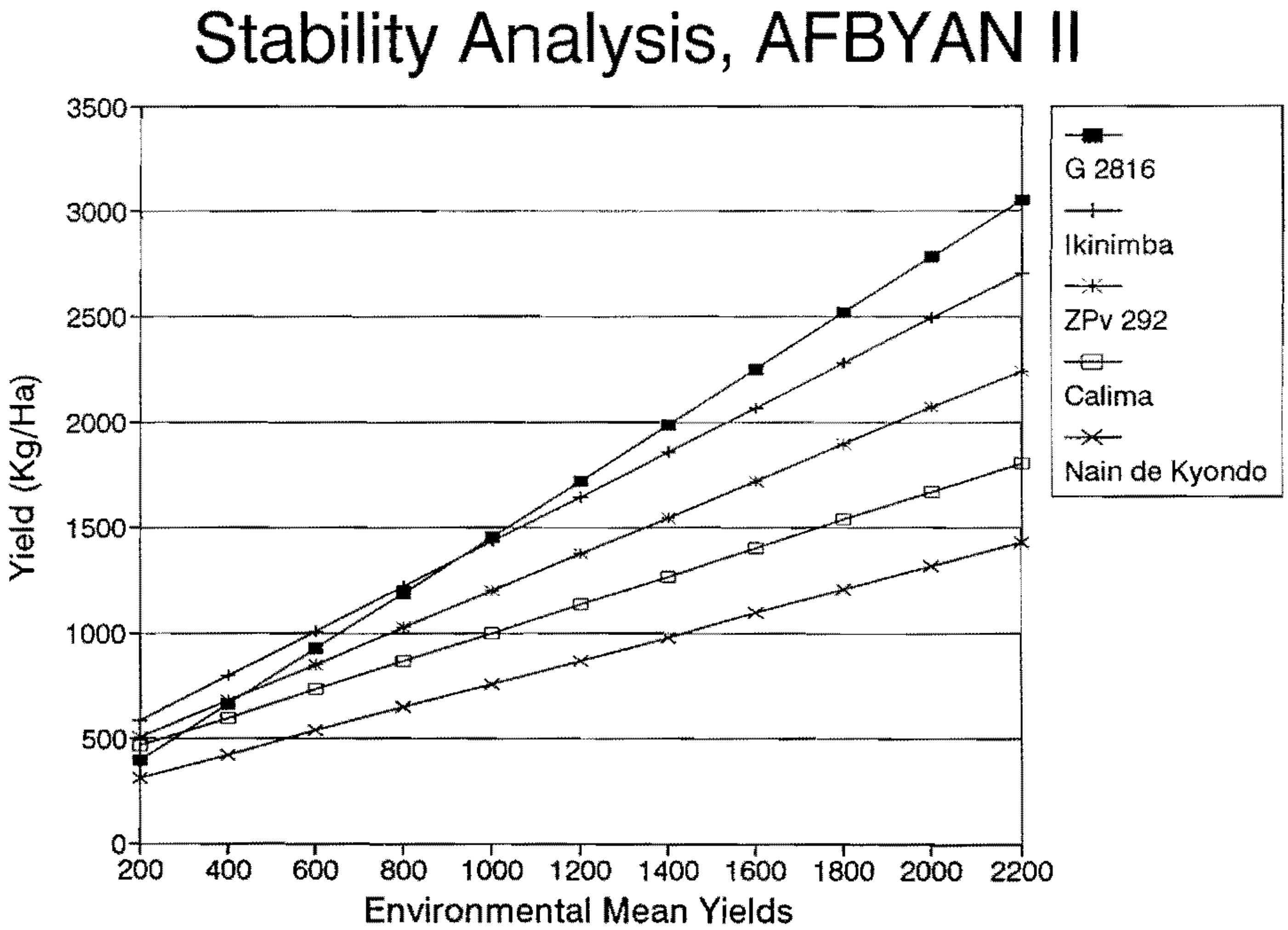
Table 5. Eigenvalues of the correlation matrix in principal components analysis with percent variation of entry by location interaction accounted for by each principal component.

	Eigenvalue	Difference	Proportion	Cumulative
PRIN1	7.46	2.98	0.298	0.29
PRIN2	4.48	1.77	0.179	0.47
PRIN3	2.71	0.60	0.108	0.58
PRIN4	2.10	0.16	0.084	0.67
PRIN5	1.93	0.57	0.077	0.74
PRIN6	1.36	0.34	0.054	0.80
PRIN7	1.02	0.12	0.040	0.84
PRIN8	0.89	0.20	0.035	0.87
PRIN9	0.69	0.14	0.027	0.90
PRIN10	0.54	.	0.021	0.92

Table 6. Pearson correlation coefficients between the first five principal components and environmental parameters in AFBYAN II.

	PRIN1	PRIN2	PRIN3	PRIN4	PRIN5
Latitude	-0.38746 0.1012	-0.07233 0.7686	-0.09067 0.7120	0.01252 0.9594	0.1720 0.481
Altitude	-0.07395 0.7567	-0.22730 0.3352	0.02139 0.9287	0.06986 0.7698	-0.2129 0.367
Soil	0.44105 0.1314	0.17989 0.5565	-0.00219 0.9943	-0.58615 0.0353	0.0409 0.894
Day Length	-0.73693 0.0041	-0.38530 0.1936	-0.04104 0.8941	0.07256 0.8138	0.2965 0.325
Change in Day Length	0.30022 0.3431	0.27425 0.3884	0.02961 0.9272	-0.57929 0.0484	-0.0853 0.792
Preplant Rainfall	0.16195 0.5642	0.06139 0.8279	0.08042 0.7757	0.40546 0.1338	-0.0616 0.827
Vegetative Rainfall	-0.29940 0.2599	-0.22539 0.4013	0.29521 0.2670	-0.06764 0.8034	0.3941 0.130
Flower/Pod Rainfall	-0.27118 0.3097	-0.14494 0.5923	0.05567 0.8377	0.32729 0.2159	0.3917 0.133
Total Rainfall	-0.20779 0.4574	-0.25972 0.3499	0.14579 0.6042	0.27893 0.3141	0.2845 0.304
Vegetative Max Temp.	0.21894 0.5434	-0.06606 0.8561	-0.05943 0.8705	0.40410 0.2468	0.4732 0.167
Flower/Pod Max Temp.	-0.03435 0.9250	-0.25085 0.4845	-0.28906 0.4179	0.37971 0.2791	0.2890 0.417
Mean Max Temperature	0.07725 0.8320	-0.17678 0.6252	-0.19399 0.5913	0.41254 0.2361	0.3861 0.270
Vegetative Min. Temp.	0.19188 0.5954	-0.21995 0.5415	0.09989 0.7837	0.32817 0.3546	0.5561 0.095
Flower/Pod Min. Temp.	0.29047 0.4156	-0.20222 0.5753	-0.02054 0.9551	0.53791 0.1088	0.6335 0.049
Mean Min. Temperature	0.24550 0.4942	-0.21213 0.5563	0.03562 0.9222	0.45055 0.1913	0.6041 0.064
Vegetative Mean Temp.	0.22041 0.5406	-0.15734 0.6642	0.02061 0.9549	0.38464 0.2724	0.5351 0.110
Flower/Pod Mean Temp.	0.15943 0.6600	-0.23415 0.5150	-0.15468 0.6696	0.50395 0.1375	0.5157 0.127
Mean Temp.	0.18400 0.6109	-0.19583 0.5877	-0.06552 0.8573	0.45745 0.1837	0.5256 0.118

Figure 1.



Stability Analysis, AFBYAN II
Yield (Kg/Ha)
3500
3000
2500
2000
1500
1000
500
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
Environmental Mean Yields
G 2816
Ikinimba
ZPv 292
Calima
Nain de Kyondo

COMMON BEAN BREEDING AT THE UNIVERSITY OF SWAZILAND 1990-1992

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ABSTRACT

The common bean (Phaseolus vulgaris L.) breeding program at the University of Swaziland was started in 1987. At that time, a screening program was started with lines from CIAT and other sources. Some of the results for the years 1987-1989 were reported in a previous paper. This paper presents the results of the main yield trials for the 1990, 1991, and 1992 seasons. In all three years there were significant differences in yield among cultivars in the Preliminary A Yield Trials (4 replications, 3 m rows, 4 rows/ plot). In 1991 and 1992 Preliminary B Yield Trials (2 replications, 3 m rows, 2 rows/plot) were also planted, but there were no significant differences among cultivars in these nurseries.Yields were low in all trials, with trial mean yields ranging from approximately 200 to 650 kg/ha and the yields of the best line in each trial ranging from approximately 550 to 900 kg/ha. This was at least partly due to bean fly infestation. Based on yield, maturity, growth habit (1 to 2b preferred), and seed color (cream with speckles preferred) the following lines from these trials were recommended for inclusion in the multi-location trials carried out by personnel of the Ministry of Agriculture and Cooperatives : AFR 247 and SUG 30 for 1991; AFR 389 and BAT 1222 for 1992. AFR 246 and SUG 45 will be recommended for inclusion in the 1993 multi-location trials. In 1990, the first successful crosses were made using lines that looked promising based on the screening program. Crosses were also made in 1991 and 1992. Segregating lines from these crosses will be handled mainly by the pedigree method. The goal of the crossing program is to combine high yield potential with acceptable maturity, growth habit, seed color and size, and disease resistance.

INTRODUCTION

In 1988/89, the common bean (*phaseolus vulgaris* L.) was grown for dry beans on 4,704 hectares in Swaziland (Anon., 1989). Thus, it is an important food crop and efforts to provide improved cultivars to the farmers of Swaziland are worthwhile.

The current bean breeding work at the University of Swaziland was started in 1987 to screen new materials and to make crosses with the most promising lines in order to develop cultivars specifically suited to Swaziland. The main criteria for selection have been high yield, early maturity, growth habit (1 to 2b preferred), seed color (cream with speckles preferred), and resistance to diseases (especially bean rust caused by *Uromyces appendiculatus* and bean common mosaic, caused by bean common mosaic virus, BCMV).

Some of the results of the screening work at the University for the years 1987-1989 were reported in a previous paper (Kuhn and Masina, 1989). This paper presents the results of the main yield trials for the 1990, 1991, and 1992 seasons. The breeding nurseries are also mentioned. Promising lines identified in the work at the University are recommended to personnel at the Malkerns Research Station for inclusion in their multi-location trials.

MATERIALS AND METHODS

All trials reported here were carried out on the Crop Production Farm, University of Swaziland, Luyengo Campus. Rows in all trials were 3m long and 0.6m apart, with either 10cm (1990 and 1992 Preliminary A yield trials) or 6cm between seeds in a row (all other trials). The 10cm spacing between seeds would give the intended plant population of approximately 167 thousand plants/ha, if all seeds grew into mature plants. The higher seeding rate was used where there was adequate seed because of previous stand establishment problems.

Preliminary A yield trials consisted of four row plots with four replications. Preliminary B yield trials consisted of two row plots with two replications. The randomized complete block design was used for all of these trials. Lines were included in these trials based on their performance in previous years (Kuhn and Masina, 1989) or their performance in the CIAT screening nurseries grown at the University in 1990 and 1991. Bonus and Umvoti were included as local checks. CO 81-120, Bill Z, and Olathe are pinto beans from the U.S.A. (Kuhn and Masina, 1989). SRDA and Tikhuba are local cultivars collected by Z.Mamba, Malkerns Research Station, Swaziland, and named after the area of collection. Market Bean 92-1 was bought from the Manzini Market. All other lines are CIAT lines.

N, P, and K were applied in accordance with the recommendation for heavy soils in the West Middleveld (Anon.1977), except that the recommended top dressing was applied with the basal dressing in 1992. Basal applications were banded. The 1990 and 1991 trials were planted in late February, and the 1992 trials in mid-February. Irrigation was not used except just after top dressing in 1990.

Yield as reported in this paper is the weight of the shelled dry beans. Harvest maturity is the number of days after planting until 90% of the plants are ready for harvest. Bean rust, bean common mosaic and black root (also caused by BCMV) severity, growth habit, and seed color were rated as described by van Schoonhoven and Pastor Corrales (1987). The number of plants per plot was based on counts. In 1990 the plants in the middle two rows were counted after harvesting the pods. In the other two years plants in all rows were counted, approximately one month before harvest in 1991 and approximately 20 days after planting in 1992.

Breeding nurseries were grown in the field in all three years. There were 9, 7, and 7 parents in the 1990, 1991, and 1992 crossing nurseries, respectively. The resulting F_1 and F_2 populations were also grown in the field. The agronomic practices were those described above. Intra-row spacing varied.

RESULTS

The results are presented in Tables 1 to 5. In all three years there were significant differences in yield and harvest maturity among cultivars in the Preliminary A Yield Trials, but there were no significant differences in yield among the cultivars in the 1991 and 1992 Preliminary B Yield Trials. Yields were low in all trials, with trial mean yields ranging from approximately 200 to 650 kg/ha, and the yields of the best line in each trial ranged from approximately 550 to 900 kg/ha. Two growth habits are recorded for some cultivars. In the case of Olathe (Table 1) and possibly other cases, I believe this is simply variation in expression, not seed mixture. In other cases, there might be some mixture of types.

Data on plant population for 1990 and 1992 were not included in the tables since there were no significant differences between cultivars in either year. The average plant populations were approximately 94, 136, and 136 thousand plants/ha in the 1990 and 1992 Preliminary A Yield Trials, and the 1992 preliminary B Yield Trial, respectively. As noted above, the 1992 plant stand notes were taken early in the season and the 1990 notes were taken after pods were harvested.

In the crossing nurseries, there were 46, 22, and 68 cross-fertilizations attempted in 1990, 1991, and 1992, respectively. Of these, 26, 11, and 28 were successful in the respective years, giving an overall success rate of about 48%.

DISCUSSION

The purpose of these yield trials was to identify lines that are promising enough to include in multi-location trials and/or in a crossing program. Keeping in mind the specific objectives mentioned above, the following lines from these trials were recommended for inclusion in the multi-location trials carried out by personnel of the Ministry of Agriculture and Cooperatives: AFR 247 and SUG 30 for 1991; AFR 389 and BAT 1222 for 1992.

In making the decision for inclusion in the 1991 multi-location trials, XAN 78 was rejected because it was felt that it's black seed color would be unacceptable to farmers and consumers. Neither AFR 247 nor SUG 30 were significantly different in yield from the local checks (Bonus and Umvoti) in 1990 (Table 1), but they are both earlier in maturity than Bonus and have had fairly consistently good yields for several years (Kuhn and Masina. 1989). Thus, I felt they deserved a wider testing. They were both tested at three locations in 1992. Although the data have not yet been published, it appears that both lines performed reasonably well but neither was outstanding.

G13536 was the top yielder in Preliminary A in 1991 (Table 2), but it was rejected because of its purple seed color. All of the other cultivars in this nursery were lower than Bonus in yield. Although there were no significant differences in yield in the 1991 Preliminary B (Table 3), I felt the two top yielders looked promising enough for multi-location testing. They were later in maturity than Bonus in this trial, and this may render them unusable if they are consistently so.

Considering the data for 1992 (Tables 4 and 5), AFR 246 and SUG 45 will be recommended for inclusion in the 1993 multi-location trials. These cultivars did not look as good in 1991, but this may have been due to poor stand (Table 2). Entry # 115 also yielded well, but appears to have a black root problem.

The generally low yield levels in these studies was at least partly due to bean fly (Ophiomyia spp.) infestation. Kuhn and Masina (1989) reported infestations of above 87% in all cultivars rated in 1989. Similar results were obtained in 1990 (data not shown), and the bean fly appears to be a problem every year. The 1992 yields may have been affected by drought, but they were fairly mature before the drought became severe.

Since the first successful crosses were made in 1990 using lines that looked promising based on the screening program, the first F_2's were available for selection this year. Segregating lines from these crosses will be handled mainly by the pedigree method. Parents for the crosses have included lines recommended for further testing, such as SUG 30, and lines that look good but have specific weaknesses, such as G 13536. The goal of the crossing program is to produce cultivars specifically suited to the conditions in Swaziland.

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Table 1. 1990 Preliminary A Yield Trial

Cultivar	Yield kg/ha	Days to Harvest Maturity	Growth Habit	Rust (1-9)
UMVOTI	888	88	1[1]	3.0
XAN 78	881	87	2b	1.0
AFR 247	865	93	2b	1.2
SUG 30	788	91	2b	1.8
BONUS	722	100	2b	3.2
BILL Z	672	76	3	6.5
SUG 29	661	96	2b	1.0
PVMX 1589	657	88	2b	1.2
REC 6	639	94	2b	1.2
G 11914	594	98	2b	1.5
SUG 19	535	90	2a	1.0
OLATHE	506	76	2b/3	6.8
CR 8193	485	91	4	5.2
CO 81-12034	382	80	2b	6.8
NURSERY MEAN	663	89		3.0
LSD (0.05)	238	4		0.8
C.V. (%)	25	2		19

[1] Initially recorded as 2a, because of unfamiliarity with the scale.

Table 2. 1991 Preliminary A Yield Trial

Cultivar	Yield (kg/ha)	Days to Harvest Maturity	Plant Population (1000s/ha)
G13536	567	124	144
BONUS	348	129	118
G 4435	294	109	103
ENTRY # 115[1]	276	125	139
A 195	269	116	89
AFR 246	233	126	99
SRDA	206	97	137
SUG 29	202	130	92
Tikhuba	180	109	97
SUG 45	165	117	58
UMVOTI	123	103	67
REC 6	120	120	83
SUG 54	117	129	60
SUG 53	101	117	59
AFR 360	99	118	43
AND 724	65	112	34
Nursery Mean	210	118	89
LSD (0.05)	155	9	33
C.V. (%)	51	6	26

[1] Entry in 1987 Halo Blight Nursery.

Table 3. Preliminary B Yield Nursery 1991

Cultivar	Yield (kg/ha)	Days to Harvest Maturity	Plant Population (1000s/ha)
AFR 389	637	123	118
BAT 1222	623	114	97
UMVOTI	511	94	144
ENTRY # 94[1]	492	143	97
MCM 5001	471	127	126
AFR 395	469	125	114
AND 756	450	129	79
SUG 44	434	118	82
AFR 454	429	130	71
88 VEF 413	421	109	109
AFR 455	415	120	113
AND 754	395	127	115
AFR 348	362	118	83
SUG 41	358	112	78
AFR 367	357	120	81
ENTRY # 93[1]	354	119	97
SUG 37	334	120	97
AFR 408	324	127	140
AFR 365	317	122	119
SUG 47	315	129	86
SUG 34	314	136	143
AND 762	281	124	165
SUG 46	263	131	58
AFR 396	262	118	93
AFR 397	262	121	81
AFR 385	260	140	64
SUG 50	258	119	117
SUG 40	248	118	38
SUG 35	247	117	110
AFR 370	242	121	122
AND 758	241	122	125
SUG 49	226	141	125
SUG 52	224	141	86
SUG 38	222	73	90
SUG 59	222	123	139
SUG 43	215	131	106
FRUTILLA	207	99	121
SUG 51	197	132	86
SUG 60	177	125	128
AND 725	173	135	86
SUG 42	171	119	69
G 4449	136	97	49
ICA 10209	125	133	81
SUG 39	122	133	79
POGONION	47	112	8

Table 3. (Continued)

Nursery Mean	306	122	97
LSD (0.05)	N.S.(286)	N.S.(33)	47
C.V. (%)	45	9	24

[1] Entry in 1990 BCMV Nursery (IBCMBRN)

Table 4. 1992 Preliminary A Yield Trial

Cultivar	Yield (kg/ha)	Days to Harvest Maturity	Growth Habit	Black Root[3] (1-9)	Common Mosaic (1-9)
AFR 246	632	96	2b	1.0	2.6
ENTRY # 115[1]	560	96	2b	2.0	1.3
SUG 45	539	94	2b	1.0	2.3
UMVOTI	479	90	1	1.0	6.0
Tikhuba	457	92	1/2b	1.0	6.3
SRDA	447	89	1	1.0	5.3
ENTRY # 93[2]	443	96	2b	3.0	1.0
SUG 50	440	94	2b	2.3	1.6
ENTRY # 94[2]	436	94	2b	1.3	1.0
SUG 53	432	96	2b	1.0	3.0
SUG 54	418	96	2b	1.0	2.6
AFR 367	372	91	2b	3.0	1.0
BONUS	365	99	2b	1.0	5.0
G 4435	325	96	1	1.0	3.3
AFR 360	299	94	2b	4.0	1.0
AND 754	176	92	1/2b	5.0	1.0
Nursery Mean	426	94		1.9	2.8
LSD (0.05)	174	4		1.7	1.2
C.V. (%)	28	3		54.0	26.0

[1] Entry in 1987 Halo Blight Nursery
[2] Entry in 1990 BCMV Nursery (IBCMBRN)
[3] Three replicates rated

Table 5. 1992 Preliminary B Yield Trial

Cultivar	Yield (kg/ha)	Days to Harvest Maturity	Growth Habit	Black Root (1-9)	Common Mosaic (1-9)
SUG 44	658	91	2b	1	1
SUG 52	647	92	2b	2	1
UMVOTI	625	88	1	1	4
AFR 455	606	92	2b	1	1
AFR 395	583	97	1	3	1
AND 758	544	93	2b	1	1
AFR 348	525	93	1	4	1
AFR 365	522	91	1/2b	1	1
SUG 47	494	94	1/2b	3	1
AFR 370	489	91	2b	5	1
MARKET BEAN 92-1	489	93	2b	1	5
A 252	469	90	3	1	1
SUG 37	461	93	2b	1	1
SUG 40	461	92	2b	1	1
BONUS	444	95	2b	1	5
AFR 408	442	96	1	1	4
AND 724	433	97	1/2b	3	1
SUG 41	419	91	2b	1	1
AFR 396	414	94	2b	3	1
SUG 38	411	94	1	1	2
AND 725	400	97	2b	3	1
88 VEF 413	400	90	1	1	4
AND 762	392	94	2b	1	1
SUG 34	383	92	2b	1	3
AND 756	372	96	1/3	2	1
SUG 49	350	95	2b	1	3
AFR 454	342	95	2b	1	3
Nursery Mean	472	93			
LSD (0.05)	NS (211)	5		-[1]	-[1]
C.V. (%)	20	2		-	-

[1] Ratings not replicated.

EFFECT OF RAINFALL DISTRIBUTION ON GENOTYPE X ENVIRONMENT INTERACTION IN BEAN GENOTYPES

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ABSTRACT

Evaluations of common bean (Phaseolus vulgaris) germplasm from CIAT were conducted in Swaziland between 1987 and 1992. A sub-set of five genotypes, which were included continuously as entries in the trials, was analysed to assess stability. The relative contribution of rainfall to genotypic stability was subsequently determined after partitioning the genotype x environment interaction into stability variance statistics assignable to each genotype. The analysis of variance showed significant differences for genotype effects in all environments used in the study. The combined analysis of variance also revealed highly significant main effects, as well as interaction effects due to genotype x environments, suggesting that a simple additive model could not be adopted. G x E interaction was subsequently partitioned into specific genotypic variance components. The results showed that Carioca, PVBZ 1782 and Bonus were unstable while BAT 1713 and PVA 894 showed non-significant stability variances and are therefore more stable.

INTRODUCTION

The potential for bean production is dictated by insolation, temperature, rainfall and, to some extent, relative humidity. Solar radiation is critical for the plants' daily biomass accumulation; temperature determines the rates of growth and development while relative humidity is particularly important in determining the course, duration and intensity of pest and diseases. Rainfall, on the other hand, dictates the relative productivity of both the site and the genotype. Across environment variation in rainfall is expected to be most important while that due to radiation, temperature and relative humidity may be considered minimal.

In bean genotype adaptation studies, the problem of genotype x environment interaction is often encountered. The consistency of performance of a genotype across environments (seasons and locations) cannot therefore be ensured, and yet it is critical in the development and release of improved genotypes. Various models have been advocated for the evaluation of G x E interaction (Lin *et al*., 1986). According to Kang and Martin, (1987), weather variables need to be used to explain G x E, in an effort to understand the causes and nature of this

interaction. To achieve this, Shukla (1972) proposed a model which is perhaps the most apt, as it offers the possibility of using environmental factors as covariates to remove heterogeneity from G x E interactions.
This study has the following objectives :
To characterise bean genotypes in terms of average yields and stability of performance across environments; and to assess the relative importance and contribution of rainfall to stability of performance.

MATERIALS AND METHODS

Bean cultivar evaluation trials were carried out at research sites during each of the seasons from 1987/88 to 1991/92. A sub-set of five bean genotypes that had been continuously tested in each of the thirteen environments were selected for an in-depth statistical study. Research sites used in these trials are located in the highveld and middleveld which differ in their agro-ecological potential, soil texture and structure, rainfall distribution, reliability and amounts, and in inherent fertility. The sites used in the study were selected because they represent regions of the country where beans are considered to have a comparative advantage over other legume crops, such as cowpea and groundnuts. A randomised complete block design in three replicates was used in this study. Randomisation was varied from location each season. Trial experimental plot sizes consisted of two rows spaced 0.6 m apart (ie. 1.2 m across rows) and 6 m in length, giving a net plot size of 7.2 m^2. The experimental area was bordered by two or more rows of a non-experimental bean cultivar. Trial management varied little between environments. Fertilizer application rates were based on soil test results which were adjusted for the specific fertilizer recommendations for the particular soil type and ecology. Rates of application were : 18 kg N ha^{-1}, 25 kg P ha^{-1}, and 18 kg K ha^{-1} of basal fertilizer which was broadcast in planting furrows and mixed prior to planting. Top-dress nitrogen was applied at about four weeks after planting using a fertilizer rate of 20 kg N ha^{-1}. All trials were hand planted by placing one seed per station at a spacing of about 10 cm between hills. Weed control was effected by hand-hoeing as and when necessary. Pest and disease control measures were not applied. Trials were harvested by hand, as and when each cultivar became dry.

Analysis of variance for genotype-environment grain yield means and combined analysis of variance across environments were computed, following procedures described by McIntosh (1983) for random environment and fixed genotype effects.

Following the combined analysis of variance and a significant genotype x environment interaction, stability variance statistics σ^2_i and S_i^2, developed by Shukla (1972) to estimate the contribution of each genotype to the G x E interaction, were determined using Kang's (1988) interactive basic programming model. Additional information relating to genotype instability was obtained through the use of covariates to remove heterogeneity due to external variables (disease and insect pressure, fertility and management differences across environments) and rainfall distribution parameters during the growing season (total rainfall, pre-season rainfall, rainfall from planting to harvest, rainfall during vegetative growth and rainfall for the post-flowering period). Shukla's equations relating to the covariate, Z_j, representing the environmental index for the jth environment is defined below:

$$Z_j = \overline{Y_{.j}} - \overline{Y_{..}}$$

where $\overline{Y_{.j}}$ and $\overline{Y_{..}}$ are defined above, based on totals over replication.

Shukla's equation for the removal of rainfall effects is defined below:

$$b_i = \Sigma_j [(Y_{ij} - Y_{.j}) - (Y_{ij} - Y_{.j})/s \times Z_j / \Sigma_j Z^2_{.j}]$$

$$= \Sigma_j [(u_i - u_{i.}) Z_j/\Sigma_j Z^2_j]$$

where b_i = regression co-efficient for the ith cultivar and Z_j a covariate for the jth environment.

The residual or remainder of the GE interaction variance, after considering each covariate, was subsequently partitioned into stability variance components for each genotype (S^2_i) using the relationship below:

$$S^2_i = \left[\frac{t}{(t-2)(s-1)}\right] \times [S_i - \Sigma i\{S_i/t(t-1)\}]$$

$$\text{with } S_i = \Sigma_{j=1}^{s} (u_{ij} - \overline{u_{i.}} - b_i Z_j)^2$$

Total sum of squares due to S^2_i were calculated by summing the individual stability-variance statistics, after adjustment by a covariate to obtain the residual sums of squares. Heterogeneity due to the covariate was ultimately determined as the difference between total sums of squares due to G x E interaction and the residual sums of squares. All equations were solved using the Basic programme (Kang, 1988).

RESULTS AND DISCUSSION

<u>Environment Description</u>: The thirteen environments consisted of two or three research sites that were used in this study during each of the seasons from 1987/88 to 1991/92. These environments thus provided a wide range of weather conditions the most important one of which was rainfall, its distribution over the phenological stages of beans as well as amounts. Table 1 summarises rainfall data and their variability for the thirteen locations used in the study. From Table 1, it is evident that large variations in rainfall were experienced both within season

and across seasons and locations. Rainfall distribution relative to the bean phenology also varied considerably, from season to season and from site to site. While total rainfall was in most instances large, and for beans adequate, much of this rainfall was recorded prior to planting. This was particularly the case in the period 1988/89 to 1991/92. Mid-crop season as well as terminal moisture stress were experienced in some of the trials.

Genotype Effects on Grain Yields per se: Genotype performance within and over the trial environments were significantly different. Table 2 depicts data for this attribute for the thirteen environments. Clearly, Carioca (Type III) was the most productive in 75% of the trials while Bonus was the least adapted at all sites. PVBZ 1782 (Type IIb) was also high yielding and recorded higher yields than Carioca in 26% of the sites. BAT 1713 (Type IIb) was also adapted while PVA 894 (Type I) performed moderately well over all sites.

Seasonal Effects on Genotype Performance: Table 2 suggests that the productivity of environments both within and between seasons varied quite considerably. Highest yields were recorded in the 1987/88 season, which not surprisingly also recorded the highest total rainfall which was well distributed; the 1991/92 season was the worst and the least productive, as expected.

A subsequent combined analysis of variance for grain yield revealed highly significant effects due to environments and genotypes, as well as a highly significant genotype-environment interaction effect. This indicates that yield means varied over environments, and thus genotype performance was not consistent. Some bean genotypes were thus better adapted to certain environments and less so in others. The genotype x environment interaction was subsequently partitioned into stability variance statistics (σ_i^2) components attributable to each of the five genotypes. The analysis of variance and the genotype stability variance estimates are illustrated in Table 3. Stability variance parameters show that Carioca, PVBZ 1782 and Bonus were significantly different from the within error environment variance, suggesting that the three genotypes were unstable. The other two genotypes (BAT 1713 and PVA 894) recorded small σ^2_i values (these were 0.07 t/ha in both genotypes) and non-significant, and can thus be characterised stable. A further analysis involving G x E partitioning revealed that the environmental index incorporating diseases, pests as well as management removed but a small part of the heterogeneity from G x E interaction. The three bean genotypes remained unstable, though their stability-variance statistics were lower. Bonus' stability index fell from 0.24 to 0.14 but remained significant. Variations in rainfall unexpectedly did not remove much heterogeneity; this anomaly, however, needs to be examined further.

To obtain additional information into the relative contribution of each rainfall parameter to the performance of bean genotypes, a multiple regression analysis was conducted. The following preliminary observations were made :

1. Pre-seasonal rainfall contributed very little to yield

variations observed.
2. Rainfall during flowering and pod formation was the most important rainfall parameter and accounted for between 25 and 75% of the variation.
3. There were variations in genotype responses to various rainfall parameters . In Carioca, 60% of the grain yield sums of squares was accounted for by the regression model; however, the effects were only significant at P=0.08. In PVBZ 1782, over 75% of variation was due to rainfall; these effects were highly significant, suggesting that the regression model accounted for a large and significant part of the total variation. In the remaining genotypes, the regression models were weak and accounted for less than 50% of the total sums of squares. This analysis, however, needs to consider the contribution of each rainfall parameter in a stepwise manner, if it is to identify those parameters that are most critical.

In conclusion it may be stated that this study is incomplete. It attempted to examine a set of bean genotypes to explain the relationship between rainfall and the G x E interactions observed. Out of the five genotypes tested, BAT 1713 and PVA 894 were stable while the other three were not. An environmental index, as defined by Kang and Martin, removed some non-additivity in the G X E but the three bean genotypes remained unstable. Rainfall, however, appears to be a critical factor to consider but here again genotypic variations in response were evident and this may be related to the type of genotype.

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Table 1. Rainfall distribution data for 1987/88-1991/92 seasons (mm)

Season	1987/88			1988/89		1989/90			1990/91			1991/92	
Period	ENV 1	ENV 2	ENV 3	ENV 4	ENV 5	ENV 6	ENV 7	ENV 8	ENV 9	ENV 10	ENV 11	ENV 12	ENV 13
Total	1047	627	1130	868	876	753	827	884	1061	973	805	325	432
Pre-season	363	315	408	767	532	536	617	616	683	580	530	247	283
Post-plant	684	311	722	101	345	217	210	268	379	393	275	78	150
Vegetative	541	185	540	37	62	134	160	236	378	282	227	68	140
Flowering	143	127	182	64	26	83	50	32	66	66	38	10	10

Table 2. Bean genotype evaluation grain yield data (kg/ha)

Season	1987/88			1988/89		1989/90			1990/91			1991/92	
Genotype	ENV 1	ENV 2	ENV 3	ENV 4	ENV 5	ENV 6	ENV 7	ENV 8	ENV 9	ENV 10	ENV 11	ENV 12	ENV 13
Carioca	1533.9	2017.1	1998.7	1139.9	774.7	810.0	1011.1	1699.9	721.6	745.6	1019.3	327.4	236.4
PVBZ 1782	1235.2	1391.9	1924.2	813.5	923.3	1110.7	985.9	980.7	561.3	561.3	995.6	127.0	278.7
BAT 1713	560.3	1899.8	1641.2	688.7	657.4	615.9	524.4	1136.8	363.1	613.4	893.5	215.6	218.3
PVA 894	582.0	1324.7	1325.5	683.4	617.2	489.4	709.3	1041.1	546.2	919.6	856.7	205.4	214.7
Bonus	287.6	977.2	909.1	331.0	605.7	313.3	168.0	280.1	240.7	328.9	852.3	128.5	135.0
Mean	843.8	1522.1	1559.7	731.3	655.6	667.9	679.8	1027.7	486.6	633.8	923.5	200.9	216.3
SE (+/-)	207.0	373.0	254.9	96.8	ns	128.6	97.1	169.9	76.4	81.8	ns	18.4	26.0
CV (%)	30.1	30.0	20.0	16.2	15.6	23.6	17.5	20.3	19.2	15.8	11.6	11.2	14.7

Table 3. Analysis of Variance and Component σ_i^2 for the Test Genotype

Source Of Variation	Degrees of Freedom	Mean Sq. (t/ha)	Grain Mean Yields (t/ha)
Environment	12	2.557***	
Rep/Env.	26	0.068	
Genotypes	4	2.207***	
G x E	48	0.147***	
σ^2 Carioca		0.220**	1.077
σ^2 PVBZ 1782		0.142**	0.894
σ^2 BAT 1713		0.07	0.770
σ^2 PVA 894		0.07	0.7327
σ^2 BONUS		0.24**	0.429
Error	104	0.0393	

STATUS OF THE VARIETY COMPONENT OF THE BEAN PROGRAM IN MOZAMBIQUE

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ABSTRACT

Yield trials of both local and introduced varieties of beans (total of 220 entries, 35% of them tested in Lichinga and 55% at Umbeluzi), have provided reliable information for proposing the multiplication of locals Manteiga, INIA-10, Encarnado and ENS-2, together with introduced Diacol Calima, PVA 773 and Umvoti. The three introduced materials outyielded all local ones and have higher resistance to rust, common bacterial blight and angular leaf spot, which are the most prevalent diseases in the region. Of a group of 25 varieties, including those proposed for multiplication, 23 of them comply with farmers' grain quality demands, namely large grain size and red or cream colors. These have been assembled as the Elite Variety Group which will be tested in Niassa, Tete, Nampula, Manica, Zambhesia, Goza and Maputo Provinces in 1993. The number of varieties so far tested provides solid information on the varieties to be recommended, and new ones to be bred.

INTRODUCTION

A bean research program was established in Mozambique in the growing season of 1990, with joint INIA and FAO funding and execution, and with CIAT's scientific support. The program is breeding oriented, with the specific objective of providing a sound variety basis to applied research directed at current and future needs of rural local populations.

Eight varieties, that had been selected by W. Heemskerk in the late 1980s, were obtained from the germplasm bank at INIA, Maputo. These were supplemented by a collection of 14 local materials made by Dr. G. Davies in Lichinga. Acceptable grain quality, which is seen by farmers as large grain size and testa color of red and cream, is established as an important breeding objective. The only two localities available to conduct the bean research program are Maputo, in the South, and at Lichinga, in the Northwest of the country. Additional germplasm was requested from CIAT from whom two IBYANs were obtained and, by the 1991 planting season, the SADC/CIAT program had provided a series of 14 IBYANs from which to select lines suited to local demands. All these materials have now been tested in replicated yield trials, most over two seasons, using the INIA varieties and the most popular local varieties as checks. Evaluations at Lichinga Experimental Station are conducted under rainfed conditions whereas work at Umbeluzi, near Maputo, necessarily relies entirely on controlled irrigation.

MATERIALS AND METHODS

About 200 lines have been evaluated at Lichinga, and about 160 lines tested at Umbeluzi. An angular leaf spot nursery has been tested at Lichinga. Of the remaining lines, 30% have been evaluated at both sites, 10% at Lichinga alone, and 60% at only Umbeluzi. The criteria for discarding entries were : disease susceptibility (scores > 5, 1-9 scale); low yield; unacceptable seed type (small size, color not cream or red); and climbing habit (type IV).

In view of the critical shortage of seed for farmers, an evaluation scheme has been established to accelerate selection and multiplication with heavy reliance on introduction :

1. Introduction of new germplasm
2. Advanced variety group (50 entries, one season of testing)
3. Elite variety group (25 entries, two seasons' testing at both sites)
4. Multiplication/Seed production group (7 lines, four local and three introductions)

RESULTS

Entries, characters and performance of materials at the elite stage of testing are presented in Tables 1 and 2. Among the local varieties, INIA 10, INIA 12, INIA 23 and INIA 83 have growth habit and grain characters similar to the local check Manteiga, from which they were presumably selected. Encarnado raiado is a red mottled type I, a scarce growth habit among local varieties. Among introduced materials, it is clear that those selected as entries in the elite variety group have high yield potential, are all type Is, and remained relatively disease free. Most are also fully acceptable. These results are encouraging, and indicate that a sound start has been made to varietal improvement.

In view of the urgent need to supply seed, the local Manteiga has been recommended, and accepted, for emergency seed programs. A few tons of seed were produced at Chockwe Experimental Station in 1992. Meanwhile, Manteiga Local, INIA 10, Encarnado Local, ENS 2, Diacol Calima, PVA 773 and Umvoti are being multiplied at both Chockwe and Umbeluzi. In 1993, the elite variety group will be planted at four sites, including Nampula, Zambezi and Tete in conjunction with the World Vision Program.

Table 1. Entries in the elite variety group in Mozambique, 1992 : characters and acceptability.

Entry	Source	Growth habit	Grain size (100 seed wt, g)	Grain color score	Acceptability score
Manteiga[1]	Lichinga	II	56	2	1
INIA 10	INIA	II	47	2	1
INIA 12	INIA	II	47	2	1
INIA 23	INIA	II	44	2	1
INIA 83	INIA	II	46	2	1
INIA 104	INIA	II	56	1	3
Encarnado[1]	Lichinga	II	47	6	1
Encarnado raiado	Lichinga	I	54	6	1
ENS 1	INIA	II	42	6	1
ENS 2	INIA	I	49	2	1
BAT 1387	CIAT	I	44	6	1
Diacol Calima	CIAT	I	56	6	1
PVA 773	CIAT	I	55	6	1
PVA 446	CIAT	I	61	6	1
Umvoti	CIAT	I	35	2	3
Bonus	CIAT	I	41	6	1
CAL 3	CIAT	I	44	6	1
CAL 38	CIAT	I	70	6	1
CAL 64	CIAT	I	57	6	1
AND 634	CIAT	I	54	6	1
AFR 300	AFBYAN	I	57	6	1
AFR 524	CIAT	I	52	6	1
DRK 44	CIAT	I	61	6	1
DRK 46	CIAT	I	65	6	1
ICA Pijao	Ethiopia	I	24	8	9

[1] Local checks.

Table 2. Performance and disease reaction of entries in the elite variety group, Mozambique, 1992.

Entry	Disease reaction (1-9)			Mean grain yield (kg/ha)[1]	
	RUST	CBB	ALS	Lichinga	Umbeluzi
Manteiga	3	3	2	653	1618
INIA 10	3	2	3	896	1700
INIA 12	3	3	2	755	1606
INIA 23	3	2	2	523	1403
INIA 83	2	2	2	470	1769
INIA 104	3	2	1	653	1618
Encarnado	1	2	2	594	2049
Encarnado raiado	2	3	2	453	2240
ENS 1	2	2	2	583	1577
ENS 2	2	3	1	657	2164
BAT 1387	1	3	2	873	1592
Diacol Calima	2	2	1	864	2086
PVA 773	1	1	1	1100	2322
PVA 446	1	2	1	962	2392
Umvoti	1	1	1	898	2263
Bonus	3	2	2	711	1113
CAL 3	1	1	1	608	1789
CAL 38	1	2	1	-	2447
CAL 64	1	1	1	-	2448
AND 634	1	1	1	-	2396
AFR 300	1	1	1	962	1732
AFR 524	1	1	1	-	2767
DRK 44	1	1	1	-	2200
DRK 46	1	1	1	-	2311
ICA Pijao	1	1	1	-	3583

[1] Mean over 3 replications for 2 years (Umbeluzi with irrigation).

DISCUSSION OF THE SESSION ON PLANT IMPROVEMENT

Aggarwal : Dr. Mushi, Ikinimba had more segregants than the other lines that I saw at Arusha. Why ?

Mushi : A truer picture will emerge when we combine the dead and live plants.

Youngquist : There were variations among plots. However, this can be evened out when all plots are harvested. The correlations between parents and off-spring is high when both are grown in the same environment. It is better to plant them in different seasons or locations.

Mushi : I agree, but this is difficult to achieve.

Youngquist : The arc sine transformation of the data might make the data seem misleading.

Mukoko : Could there have been less pressure if no fertilizer was used ?

Mushi : Even though fertilizer was applied (at the normal rate of 60 kg/ha of P205 and 30 kg/ha of N), BSM pressure at the site was high, even in Lyamungu 85.

Ampofo : Actually, no fertilizer was applied!

Nahdy : Dr. Nchimbi, F1 lines can be tested with *Zabrotes* if there is no suitable equipment for use of electrophoresis.

Nchimbi : Feeding assessment using *Zabrotes* requires fairly large numbers of seeds. However, even where the number of seeds are low, electrophoresis can be used.

Allen : Can you include materials from elsewhere in your crosses?

Nchimbi : Yes, we shall include materials from elsewhere.

Giga : Can we modify Dr. Cardona's screening technique to allow for the use of smaller numbers of seeds ?

Nchimbi : Point noted. We shall try the use of 6-8 seeds from the test and compare results.

Allen : Dr. Aggarwal, why are there scores of 3 for BCMV in MCM lines which possess the I and bc3 genes ?

Aggarwal : Evaluation of symptoms of BCMV might have been wrong.

Mitti : Dry weather has an effect on lime reaction. Do you not think that the drought might have affected response to your liming ?

Aggarwal : We used $CaCO_3$

Edje : It is advisable to report yield in g/m2 or kg/ha and not g/plot, which is effectively meaningless.

Mushi : I wish to suggest that entries be tested in more than one country, not just in Malawi.

Aggarwal : Testing entries in several countries involves a considerable amount of work. I suggest that interested countries do the testing themselves.

Mushi : I suggest that the number of entries be reduced and more finished products are sent to countries, especially where the number of staff are too few to handle a heavy work load.

Edje : There are a few sites in Malawi that could be representative of sites in other countries. Could you not have more sites, including Bvumbwe, since Bunda College is not really a bean growing area ?

Mushi : Dr. Youngquist, how do you obtain quantitative data in self-pollinated crops ?

Youngquist : A diallel cross is the first attempt.

Mushi : The MSTAT package is not as efficient as SAS in the analysis of data from mixed models.

Youngquist : I shall check on the SAS package in CIAT concerning regulations since subscriptions to SAS are on an annual basis. I would be willing to organize a course on the use of SAS, if there was an approved request.

Mushi : In your analysis of principal components, how much variability was taken up by PC1 and PC2 ? Why did you go as high as PC5 ?

Youngquist : PC1 and PC2 account for 30% of the variability of the entry x environment interaction. The higher components account for lesser amounts of the variability, but may give some insight to environmental parameters affecting genotypic adaptation. Specifically, minimum temperature may be important but this would have to be tested in the future.

Aggarwal : AFBYAN II contained both bush and climbers. Could these be analyzed separately ?

Youngquist : Yes.

Pomela : Are you confident that PCA should be used ?

Youngquist : PCA is only a tool. It gives us an idea of what could be tested next.

Pomela : Can PCA be used to group fields in Lesotho ?

Youngquist : PCA is not the best tool for grouping entries for locations.

Aggarwal : With reference to Kuhn's paper, AFR 524 was also among the best 20 entries at Bunda College. Some lines may have wide adaptation.

Arias : This illustrates the use of the AFBYAN.

Edje : The selection criteria used by Arias appear to be too harsh. For instance, you have rejected type IV, while I know that climbers are being grown at Lichinga and in other similar environments in Mozambique.

Arias : There is need to have a solid basis for research and this is what we are attempting to achieve.

Allen : I agree with Todo : type IVs should not be discarded. I also note the development of new sites including Tete where one might expect materials that perform well at Msekera and Bunda to be useful.

Bosch : What is meant by environment in these papers ?

Youngquist : "Site" as well as "year" can be referred to as environments.

Edje : The term "pass over" was used frequently by Kuhn during his discussion. Do you mean that you do not discuss your results and entries with Mamba before materials are tested on-farm ?

Kuhn : We do discuss entries and share results, but pressure of work does not permit visits to on-farm trials.

Allen : Your yield levels were rather low, presumably in part due to low plant stand. Might it not be useful to use two levels of management ?

Kuhn : Yes, this can be tried to improve stand and hopefully yield.

Allen : Entry 13356 was not carried forward because it is purple in colour. Are we not over emphasising colour in this instance ? Please do note that changes in preference are sometimes made, and we should not be "pussy footed" about colour.

Kuhn : The variety with purple colour was assessed by workers and farmers on the variety release committee before we decided to discard it.

SESSION 6 :

GROUP DISCUSSION IN THE FINAL SESSION

Allen : The purposes of this final session are essentially four-fold : (i) to assess research progress and appraise its quality, with reference to components of research sub-projects each of which is then made accountable to peers in the region; (ii) to formulate outlines over time of future research to be undertaken, with a view towards increasingly Pan African collaboration; (iii) to identify gaps between regional collaborative research sub-projects in the overall regional research agenda, and so to seek additional proposals for research on priority constraints for a full portfolio; and (iv) to estimate the minimum sum at which individual sub-projects are viable, and to allocate funds proportionally within a given sub-project. Sector diagrams are useful in such allocation, with components being assigned percentages of the total resources available.

Participants are asked to contribute to one of four discussion groups that will focus on research of a particular discipline (agronomy/farming systems; abiotic constraints; entomology; and pathology), and a brief report to plenary is invited from a rapporteur chosen by each group.

Mitti (on behalf of the farming systems group, comprising also Mamba, Dlamini, Arias, Edje and Youngquist) : The survey is the only component of the cropping systems research sub-project in progress so far. We are stuck, because of the lack of data coming in. Future research should focus on four areas : (i) Intercropping of beans with maize (and/or cassava, bananas/coffee), and appraise opportunities for climbing beans, in relay or double cropping; (ii) Hedgerow intercropping for soil conservation, and production of stakes for climbing beans; (iii) Green manures in the improvement of traditional systems (e.g. Fundikila, tumba) and the possible incorporation of rock phosphate; and (iv) Utilization of wetlands on hydromorphic soils (e.g. dambos, mbuga, vlei). Linkages with scientists in other disciplines are seen as important for technical 'back-stopping'. Resources available were allocated by the group as follows :

Component	Allocation (%)	Lead countries
Maize intercropping	45	MW (TZ)
Hedgerow intercropping	15	ZA (TZ)
Valley bottoms	10	TZ (MW, ZA)
Green manures	10	ZA (MW)
Surveys	5	-
Cassava intercropping	5	ZA (MO)
Linkages	5	-
Coffee/banana intercropping	3	TZ
Banana intercropping	2	TZ

Bosch : I want to raise the issue of risk involved in cultivating valley bottoms. With experience from the Kisii Project, catchments can be destroyed and dambos may dry up, but drought increases the pressure on such valley bottoms.

E. Pomela : The group deserve a reprimand for having failed to mention weeds in their discusion !

Mkandawire (on behalf of the abiotic constraints group, comprising also Lupwayi, Bosch, van Coller, E. Pomela, Mulila-Mitti and Aggarwal) : Gaps in existing research are seen by the group as low pH (in the context of Al) and molybdenum (in the context of BNF). The sub-projects that are currently supported by the network are :
(i) Drought, with components of : mechanisms of tolerance; the ABDREN; breeding for drought tolerance; and a survey of agronomic practices used to avoid drought stress.
(ii) Biological nitrogen fixation, with components of : collection of base-line information on N deficiency; screening germplasm for improved fixation; screening strains of *Rhizobium* for efficiency; and on-farm testing of identified materials.
(iii) Low phosphorus, with components of : determination of the critical level of P at which screening is best done; evaluation of the ANSES; screening of selected materials across a P gradient; rock phosphates; and breeding for low P tolerance.
In terms of progress, the ABDREN is seen by the group to be making good progress, but research on mechanisms is both slow and difficult (roots seem to play a large role). We want now to use two sites, at contrasting altitude, using materials of different growth habit and repeating for three years. The collection of materials from drought prone areas (e.g. LO, NA) might be useful, screening at three key locations. An additional component of the drought work should be the characterization of drought environments. Work on BNF is only just starting. Research leadership needs to be defined, and work on molybdenum considered. The low P sub-project is also just taking off. The critical level for screening has been determined, using the AFBYAN. The distribution of funding within sub-projects was allocated by the group as follows :

Drought

Component	Allocation (%)
ABDREN	40
Agronomic practices	25
Tolerance mechanisms	15
Characterization of drought environ.	15
Breeding for tol.	5

BNF

Germplasm screening	40
Strains screening	30
Base-line info.	15
On-farm testing	15

Low P

Rock P etc.	50
ANSES	20
P gradient	20
Breeding for tol.	10

Giga (on behalf of the entomology group, of L. Pomela, Mushi, Nahdy, Ferede, Davies, Nchimbi-Msolla, Nsibande and Ampofo) :
Our group focused on research on bruchids, bean stem maggot and *Ootheca*. With regard to bean stem maggot (BSM), work has been concentrated on sources of 'relative resistance', population dynamics and ecology. Work on control has been concerned with a combination of cultural and chemical components. Research on loss estimates (KE, UG) has been rather unsatisfactory, but satisfactory progress has been made with studies of population dynamics as well as with resistance. We need to continue screening to find higher levels of resistance, to do more work on control, especially integrated management (IPM) such as Davies' approach. Breeding for resistance is seen as important and needs greater emphasis. There remains a need for the collation of information on *Ophiomyia* species distribution in some countries. Further work is needed on ecology, especially at screening sites, and more attention should be given to the identification of reservoirs. The key factors governing mortality need to be determined, then perhaps opening the door to biocontrol. The distribution of funding within the BSM sub-project was allocated by the group as follows :

Component	Allocation (%)
Germplasm screening & breeding	50
Control, IPM	30
Population dynamics	10
Interactions with root rot	10

Ootheca is seen as an emergent problem and proposals for submission to the Steering Committee are needed. The countries where *Ootheca* seems most important are Tanzania and Malawi (also KE, UG). Inititai emphasis should be placed on ecology and population dynamics, including the factors and triggers to mortality. But an immediate solution to *Ootheca* damage is necessary, and research on short-term control should include screening of chemicals, spray timing and cultural control measures, the latter depending on population dynamics data. Allocation to possible components of a sub-project, supplemented by post-graduate research (e.g. economic thresholds) should be :

Component	Allocation (%)
Ecol., population dynamics	60
Short-term control	20
Species distribution	10
Economic thresholds	10

Work on bruchids is being conducted in Uganda, Zimbabwe and Tanzania, and includes surveying. More information is needed on species distribution, especially in countries like Mozambique and Swaziland, to help target RAZ lines where *Zabrotes* occurs. On-farm trials are needed for cultural practices, and loss assessment (beyond that already done in Uganda) is needed. Work on the incorporation of resistance from the RAZ lines into locally adapted materials is also needed. Allocation of resources is recommended as follows :

Component	Allocation (%)
Surveys	10
On-farm trials	25
Screening work	40
Loss assessment	25

Sohati (on behalf of the pathology group, of Lana, Mukoko, Nahimana, Kuhn, Teri and Allen) : the group considered anthracnose, angular leaf spot (ALS), rust, common bacterial blight (CBB) and BCMV. It was noted that work on anthracnose was in progress in Zambia (Haciwa) and Tanzania (Mwalyego), with links outside SADC to KE, ET and RW. Most current work addresses pathogenic variability; emphasis in research were seen in need of evolving :

Component	Allocation (%, 1992)	Allocation (%, 1993-4)
Pathog. variability	70	35
Resistance screen	30	30
Breeding	0	20
Varietal mixtures	0	15

Allocation of resources to the anthracnose sub-project as a whole were recommended to be :

Transport	35%
Field supplies	30
Labour	20
Lab. supplies	5
Office supplies	10

Work on CBB is to be conducted in Tanzania (Mabagala), Zimbabwe and Uganda (Opio and Musaana). Research components should evolve as follows :

Component	Allocation (%, 1992)		Allocation (%, 1993)
Crop loss	25}		0
Regional nursery	25}	Uganda only	20 (UG, ZW)
Pathog. variation	25}		0
Resistance screen	15}		0
Breeding	10}		40 (UG, ZW)
Landraces	0		40 (TZ, UG)
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Allocation of resources to the CBB work should be :

Field supplies	40%
Labour	40
Lab supplies	15
Office supplies	5

The group recognized that the lack of work on ALS was an important gap, and the sub-project is in need of revival. Interest was expressed from Swaziland (Teri and Kuhn) in drafting a research proposal on the genetics of host-pathogen interaction and breeding for resistance which, it was suggested, establish links with work in Zaire (Pyndji) and at Arusha in Tanzania. It was suggested that ALS research should begin with a study of pathogenic variation and genetics (60%), and the assembly of a regional nursery and host differentials (40%) in the first year (1993), embarking on resistance breeding the following year.

As regards rust, it was agreed that no commitment to a regional sub-project be made until work in progress in eastern Africa (ET, Habtu) had been evaluated for its relevance to SADC.

The allocation of resources to the components of the BCMV sub-project (now combined with the aphid sub-project) was advocated to be :

Component	Allocation (%)
Resistance breeding	65 (ZW)
Res. mechanisms	9 (TZ, ZA, UG)
Strain monitoring	8 (TZ)
Aphid vector biology	9 (ZA)
Wild reservoirs	9 (UG, ZW)

Proportional fund allocation to BCMV was agreed as follows :

Field supplies	30%
Labour	30
Travel	20
Lab. supplies	15
Office supplies	5

In terms of total resources for pathology sub-projects, it was agreed that allocations should be made thus :

Sub-project	Allocation (%, 1992)	Allocation (%, 1993-4)
Anthracnose	50	30
BCMV	35	15
CBB	15	15
ALS	0	40
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Allen : I hope that you will all agree that this session has been a very useful exercise. It is fully appropriate that a regional forum like this workshop should take part in setting research priorities and in allocating resources available to the regional network to scientific problems. By doing so today, we have not only helped guide the Steering Committee's decision-making over the next two days, but also we have set up a model for future collaborative research planning for the SADC region.

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