Workshop Proceedings
Actes de Seminaire

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

PROCEEDINGS OF THE SECOND WORKSHOP ON BEAN RESEARCH IN EASTERN AFRICA

NAIROBI, KENYA
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Edited by J. Barry Smithson

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PREFACE

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

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

Publications in this series include the proceedings of workshops held to assess the status, methods and future needs of research in selected topics that constrain production or productivity of this crop in Africa. The present publication documents recent research carried out in Eastern Africa, and includes results, peer reviews and future plans of collaborative regional projects supported by the network.

Publications in this series currently comprise:

No. 1 Bean Fly Workshop, Arusha, Tanzania, 16-20 November 1986.
No. 2 Bean Research in Eastern Africa, Mukono, Uganda, 22-25 June 1986.
No. 3 Soil Fertility Research for Bean Cropping Systems in Africa, Addis Ababa, Ethiopia, 5-9 September 1988.
No. 4 Bean Improvement in Africa, Maseru, Lesotho, 30 January-2 February 1989.
No. 5 L'Amelioration du Haricot dans la Region des Grands Lacs, Kigali, Rwanda, 18-21 Novembre 1987.
No. 6 First SADCC Regional Bean Research Workshop, Mbabane, Swaziland, 4-7 October 1989.
No. 7 Second Workshop on Bean Research in Eastern Africa, Nairobi, 5-8 March 1990.

Financial support for the regional bean projects comes from the Canadian International Development Agency (CIDA), the Swiss Development Corporation (SDC) and the United States Agency for International Development (USAID). This publication was supported by CIDA and USAID.

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

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

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

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

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ACKNOWLEDGEMENTS

CIAT wishes to thank the Government of Kenya for permitting the workshop to be held in Nairobi.

The organizing committee expresses its gratitude to Dr C.G. Ndiritu, Director and Mr Rutto, Deputy Director, Kenya Agricultural Research Institute and to Mr S. Njuguna, Director, National Horticultural Research Station for their support. Assistance offered by members of KARI's Grain Legume Programme is also appreciated.

Logistical aspects during the workshop were ably managed by Ato Abadi Haile of CIAT Debre Zeit and additional assistance provided by CIMMYT's Nairobi office is also acknowledged with thanks. Mrs Julie Scott and Falcon Travel Services Ltd efficiently organised participants' travel. Mrs Gladys Mukoyani toiled long hours to provide full secretarial services to the workshop.

Word processing of these Proceedings was competently and cheerfully carried out by W/o Abesha Hailemichael, W/o Eskedar Kebede and W/t Simegn Tarekeng of CIAT Debre Zeit.

CIAT wishes to express its thanks to the Canadian International Development Agency and the United States Agency for International Development for their financial support for both the workshop and these Proceedings.

SESSION I: OPENING SESSION

WELCOME ADDRESS

Mr S.K. Njuguna

Director, National Horticultural Research Centre, Thika

Director, KARI, Dr Cyrus G. Ndiritu, CIAT Regional Coordinator, Dr Roger A. Kirkby, CIAT representatives, Workshop organizers, Distinguished guests, Participants, Ladies and Gentlemen.

It is a great pleasure to welcome you to Nairobi, Kenya for the Second Regional Workshop on Bean Research in East Africa. Although the first workshop was held at Mukono, Uganda approximately three years ago, the resolutions and recommendations emanating from that workshop have been a major catalyst on bean development in this region. In Kenya, beans are important and indeed in eastern Africa because they are a major source of protein for millions of the people in the region. The total area under bean production in Kenya between 1977/78 and 1986/87 rose from 282,983 hectares to 525,749 hectares with corresponding average yield increase from 704 kg/ha to 829 kg/ha (Gitu and Ngalyuka, 1989). This yield increase was made possible by release of six high yielding bean varieties with multiple resistance to major bean diseases such as bean common mosaic virus, anthracnose, halo blight and angular leaf spot.

Beans are also known to be efficient in fixing atmospheric nitrogen thereby enriching the soil and minimizing the need for costly commercial fertilizers. Beans are an important component of mixed cropping systems which are typical of small scale subsistence farming. These aspects emphasize the relevance of this workshop.

I therefore hope that this Second Regional Workshop on Bean Research will provide an appropriate forum for discussing ways and means of enhancing the development of this important commodity. This workshop has attracted eminent bean scientists from Kenya, Madagascar, Mauritius, Sudan, Tanzania, Uganda, CIAT and other invited guests who will be expected for the next four days to come out with recommendations which will contribute significantly in giving direction for future bean research activities in eastern Africa.

I am gratified to have been associated with your past performance and I am confident that this seminar will be a success. To the sponsors of this workshop we are very thankful.

Finally, it is now my great privilege to request the gentleman who made the present collaboration between CIAT and KARI possible and that is none other than Dr Cyrus Ndiritu, Director, Kenya Agricultural Research Institute to address the participants and open the workshop officially.

Thank you very much.

References

Gitu, K.W. and A.K. Ngalyuka. 1989. Agricultural and Livestock Data Compendium, Ministry of Planning and National Development, Nairobi.

OPENING ADDRESS

Dr C.G. Ndiritu

Director, Kenya Agricultural Research Institute

Mr. Chairman, Distinguished Guests, Officials of CIAT, USAID and CIDA, Ladies and Gentlemen.

It gives me great pleasure to be with you on this important occasion of the Second Regional Workshop on Bean Research in Eastern Africa. On behalf of the Government of Kenya and the Kenya Agricultural Research Institute, permit me to have the honour to welcome all of you to Nairobi for the workshop. To our visitors from outside Kenya I wish to extend a very warm hand of *KARIBU* to Kenya and urge them to take advantage of any available opportunity outside the workshop time to see for themselves what Kenya can offer in other fields e.g. tourist sceneries and other areas.

Mr Chairman, I am informed that this workshop is the second one of its kind addressed to legume improvement to be held in Nairobi since 1979. However, under the auspices of CIAT's regional programme on beans, it comes after the one which took place in Uganda some three years ago. We in Kenya feel privileged to be afforded the opportunity to be hosts to this important bean forum.

The role of bean in human nutrition in the region is indeed very appreciable. It provides almost half of total dietary protein in Burundi and Rwanda and forms a major supplement to the starch diets (maize and sorghum) in eastern Africa. The bean crop is also seen as essential to redress protein deficiencies usually observed in starch-based diets e.g. banana based diets in Uganda.

In Kenya, common bean is the most important pulse and second only to maize as a food crop. It is estimated that over 500 thousand hectares of beans are cultivated annually with an average yield of 500 kg/ha. These yields are remarkably low considering potential bean yields. Furthermore, the demand for beans is expected to increase with rise in population within a limited land available for cultivation. Nutritionally beans contribute 4.6% of calories and 10.2% of protein to Kenya's national diet.

In 1983/84, it was estimated that 13.4% of Kenya's high and marginal agricultural potential land was under maize and bean intercrop. Production of beans during the period 1980 to 1985 ranged between 1.3 and 3.2 million bags. Kenya's National Food Policy Strategy Paper estimated a domestic bean requirement of 344 thousand tonnes in 1989 for self sufficiency. This demand is expected to rise to over 500 thousand tons by the year 2,000. Unless production is intensified, it is unlikely that this and future targets could be achieved. Yet the crop is so important that, taken together with peas and groundnuts, beans provide both more protein and calories per kilogram basis, and in the high potential and marginal areas per hectare basis, than do beef and other meat sources. Since these other protein sources are too expensive to be consumed in nutritionally adequate quantities by the poor, increase in production of beans has a major bearing on most Kenyan's health.

Mr Chairman, I have taken the liberty to detail the critical importance of beans in our food economy to set the background for my next area of address which is a central theme in this workshop today. The regional bean research programme, as most participants know, has three major objectives. These may be summarized as:

1. to increase the productivity and production of food beans through breeding and selection of higher yielding genotypes;

2. to develop more productive systems of cropping using new cultivars and varietal mixtures i.e. genetic improvement; and,

3. to strengthen national research programmes to make them appropriate and sustainable nationally.

To meet these objectives, the network has three separately funded regional bean programmes implemented in such a way that it exploits advantages of decentralization, supports national programmes in conceptualizing, planning and carrying out field research and encourages and funds purposeful collaboration among national research programmes.

This approach is operational through several research activities namely:

1. collaborative research;
2. germplasm exchange;
3. on-farm research; and,
4. training.

Briefly, the collaborative activities integrate regional trials in national programmes rather than let them stand alone, through efficient use of limited resources, through concentration of effort of different national programmes upon complementary aspects and enhancing the planning and analytical ability of national programme scientists. Germplasm exchange enables access to promising germplasm and allows quick identification of new varieties useful in extension programmes. The on-farm research programme enables clear understanding of farmers' constraints and facilitates better entry of innovations acceptable to producers and consumers. Training, an integral part of the programme, aims to develop sustainable national human resources through informal and formal regional courses and degree courses.

I would like to point out that KARI supports this collaborative work facilitated by CIAT aimed at finding solutions to bean production constraints. A survey of bean production constraints has been conducted in some parts of the country and the exchange of elite bean germplasm has been facilitated. In addition, several of our research scientists have received short-term training at CIAT headquarters. The programme has also enabled Kenyan scientists to have access to regional and international conferences. Meetings like this also facilitate contacts and exchanges of technical information among research scientists. I am convinced, therefore, that under the CIAT regional programme, Kenya and other participating countries stand to benefit substantially.

Mr Chairman, our national objectives as they relate to bean research are meant to contribute enormously to the country's food security and food demands. These objectives include the realization of increased and stabilized yields through the development of appropriate bean varieties and improved technology in production and utilization.

The strategy for attaining the desired objectives involves a multidisciplinary approach requiring the collaboration of plant breeders, agronomists, pathologists, entomologists, seed experts, socio-economists and extension staff.

KARI allocates a major part of the budget to human resource development as it believes that any strengthening and sustainability of the programme will depend on the capability of local personnel. This is an area where CIAT can assist KARI tremendously and we would like to appeal for more effort.

Ladies and Gentlemen, I have noted from the programme that many scientists' papers will be presented in the course of this workshop all attempting to provide answers to bean production constraints. During this occasion scientists from different countries will have the opportunity to know one another and exchange scientific views. This should auger well for bean research and development in the region and internationally. Nevertheless, we should bear in mind that our prime target is the farmer. In this respect the results of your deliberations would have to be translated in a manner beneficial to the farmer.

Mr Chairman, I wish to challenge you, that for this workshop to be considered a success, you should come out with firm and affordable strategies on how to address major constraints facing food beans in the various countries of this region. The principal natural constraints are diseases and pests, low soil fertility and soil moisture deficits. Failure to apply fertilizers and pesticides results in poor yields and current production increases are achieved mainly through area expansion. We currently have a narrow local germplasm while the identified sources of genetic resistance to diseases occur in poorly adapted types which are also not preferred by consumers.

There is also need to more aggressively train scientists in bean research as well as provide adequate facilities and infrastructure. This programme should also more aggressively address the issue of information exchange on research methodology, bean germplasm literature and results among national programmes so that such information can reach, not just bean researchers but also other scientists, extension officers and even policy makers. It is only through efficient and timely information transfer of any breakthrough or potential successes that we can claim to have achieved our objectives in the research and development of this important food crop.

Mr Chairman, I wish to take this opportunity to express our gratitude to CIAT for facilitating this workshop and to CIDA and USAID for the financial support they are giving the programme. I would like to assure them of continued Kenya Government support in this noble course.

Mr Chairman, before I conclude, I would like to draw your attention to one related activity. I am informed that immediately after this workshop, from 9 to 13 March, you will hold your Annual Regional Bean Steering Committee Meeting. I am informed that apart from reviewing the regional progress reports and summary of 1989 research highlights, this meeting will consider proposals for new collaborative research projects in priority areas. I would like to let you know that we shall be keenly following the meeting agenda and are going to expect a useful output from this forum as this will be all important for the success of our national bean research and development programmes in our respective countries. Before I conclude my remarks, Ladies and Gentlemen, let me wish you very fruitful and successful deliberation in this workshop. I also wish our visitors a pleasant stay in Kenya.

Ladies and Gentlemen, it is now my very pleasant duty to declare this Second Regional Workshop on Bean Research in Eastern Africa, Officially Open.

Thank you.

INTRODUCTION TO THE WORKSHOP: DEVELOPMENT OF A COLLABORATIVE RESEARCH NETWORK ON BEAN IN EASTERN AFRICA

R. A. Kirkby

CIAT Regional Programme on Beans in Eastern Africa, Ethiopia

This meeting is the second multidisciplinary workshop on *Phaseolus* bean research to be held in eastern Africa since the start of the regional programme. It is a pleasure to see many of the participants from our first workshop, held in Uganda in 1987, as it is to meet many relative newcomers to the network. We are 53 participants from seven countries in the region and from several international organizations, including the Canadian International Development Agency (CIDA) and the United States Agency for International Development (USAID). The financial support of CIDA and USAID has been crucial to the development of these and other regional activities.

Kenya is a very appropriate meeting place for us. It is the region's largest producer of beans and includes areas where the crop is of particular importance in people's diets. In parts of Kisii District in Nyanza Province, having a population density above 500 persons per square kilometre, bean production averages 66 kilograms per person, mostly consumed at home. Research on bean is being carried out at several locations in Kenya and papers will be presented from the Kenya Agricultural Research Institute, from the University of Nairobi and from the Laikipia Rural Development Project.

The regional network in eastern Africa developed out of two consultative meetings of national research programmes and CIAT held in Malawi and in Colombia early in the 1980s. Attention was drawn to the fact that production increases were being obtained through area expansion rather than by yield increases. More recently, Gitu and Ngalyuka (1989) have shown that area expansion in Kenya has been much greater for bean than for maize. Analyses by CIAT suggest that demand for beans in Africa will grow by about 1.7 million tonnes, or 72 per cent, between 1985 and 2000 (Table 1). This growth in demand, much larger than is expected in Latin America, is attributed partly to urbanization in Africa and to low average incomes. Economic pressures, which can result in a shift from a meat-based to a bean-based diet, are not unknown even to participants at this workshop.

Table 1. Recent Bean Production Versus Future Bean Demand.

	Production 1984-86 ('000 t)	Demand 2000 ('000 t)	Required increase ('000 t)	Required increase (per cent)
Africa	2352	4046	1694	72
Latin America	4459	5940	1481	33

Source: FAO (1985, 1986, 1987); CIAT (1989)

Since 1985, an active network of bean researchers has grown up in eastern Africa, principally among the countries of Ethiopia, Kenya and Uganda where the crop is most important. Regional scientists in agronomy, breeding, economics and training are attached to the national programmes of either Ethiopia or Uganda and work across the region. The network also meshes with similar bean networks in the Great Lakes and southern Africa to ensure scientific exchange across the bean growing areas of Africa (Figure 1).

Collaborative Research

Satisfying the increase in demand for beans expected during the 15 years following the start of this network will not be easy. Even if the area under bean were to continue to expand at the historic annual rate of 1.9 per cent, average yields must increase by 308 kg/ha or 48 per cent. Ethiopia and Uganda in particular have devoted considerable effort to improving their understanding of bean production, diagnosing constraints and identifying research opportunities. Among the most frequently mentioned research opportunities are the development of new cultivars having improved levels of resistance to bacterial blight, anthracnose and beanflies and tolerant to soils of low fertility. Over 4,000 germplasm materials have been evaluated by these two national programmes since 1986, many from CIAT, but also from other national programmes in Africa and elsewhere.

Advancing of materials within national programmes feeds back into regional nurseries, now being developed in eastern Africa following a model originating in the Great Lakes (Figure 2), and into an African Bean Yield and Adaptation Nursery (AFBYAN). The AFBYAN in turn has been useful, for example in Uganda, as a source of adapted materials that can produce relatively rapid releases. New cultivars released by national programmes include a growing number that have resulted from collaboration with either CIAT or through the regional networks (Table 2). The development of on-farm trials has been another vital component in testing promising germplasm and cultural practices for performance and acceptability when managed by farmers.

Besides regional trials and nurseries, a second mode of collaborative research is the regional research subproject. A set of regional subprojects agreed by member countries enables a division of labour around priority topics, avoiding unnecessary duplication of effort. As with all network activities, subprojects are approved and funds allocated by a Steering Committee in which each country is represented.

New proposals, which may be submitted by any national scientist or group, are evaluated by the following criteria:

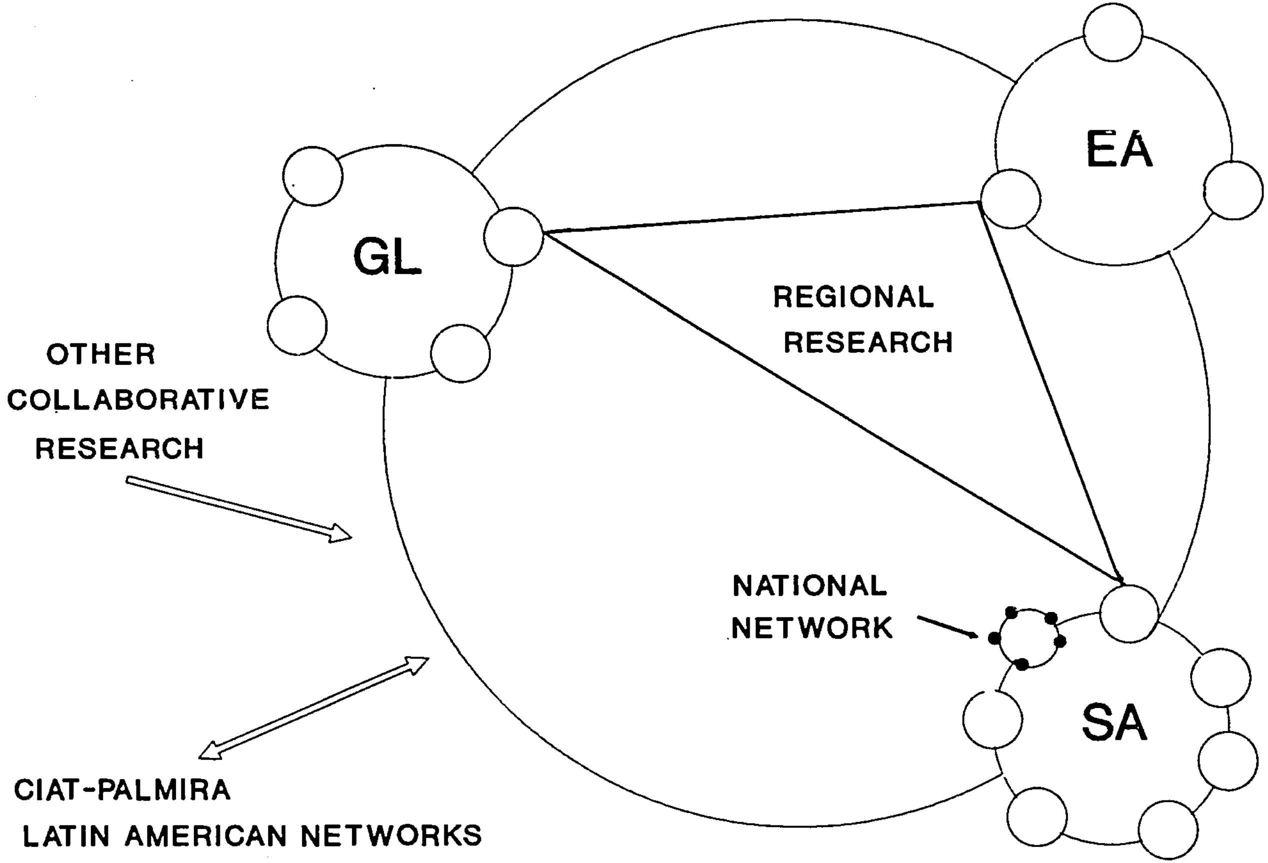
- Does the proposal respond to a regional priority?

- Are useful results likely within a reasonable period?

- Does the proposer adequately define the collaborators and their responsibilities, and the national and regional contributions that would be needed?

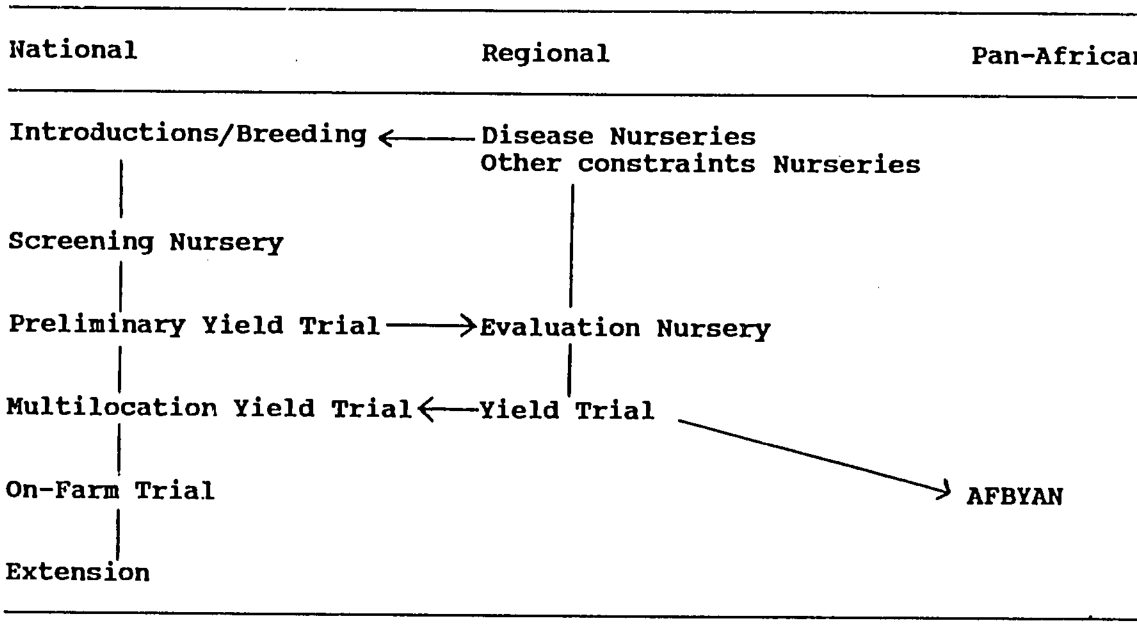
- Can the lead country or countries provide researcher(s) with adequate experience, basic research infrastructure and suitable agroecological conditions or hotspots?

Figure 1. African Bean Network



EA: EASTERN AFRICA REGION
GL: GREAT LAKES REGION
SA: SOUTHERN AFRICA (SADCC) REGION

Figure 2. Scheme for linking national and regional bean variety trials.



Source: after Davis (1989)

Table 3. Lead Countries in Regional Research Subprojects in Africa, 1989.

Topic	Eastern Africa	Great Lakes	Southern Africa
Breeding/Protection			
ALS		Zaire	Malawi
Anthracnose		Burundi/Rwanda	
Ascochyta	Uganda	Rwanda	Tanzania
BCMV	Uganda	Rwanda	Tanzania
CBB	Uganda	Burundi	
Rust	Ethiopia		Tanzania
Beanflies	Ethiopia	Burundi	Tanzania
Bruchids	Somalia		
Aphids			Zambia
Nematodes			Tanzania
Agronomy			
Nitrogen fixation	Ethiopia/Uganda	Rwanda	Malawi
Low phosphorus/acid soils		Zaire	
Climbing bean technology		Rwanda	
Maize/bean association		Zaire	Zambia
Drought	Ethiopia		Malawi

Table 2. Bean Cultivars Released in Africa from CIAT Germplasm and Activities

Country	Cultivar name	CIAT Identification
Burundi	Calima	G 4435 (Diacol Calima)
	Khaki	A 410
Rwanda	Rubona 5	G 4523 (ICA Palmar)
	Ikinyange	A 197
	RWR 221	Rubona 5 x Wulma
	Umubano	G 2333
	Muhondo	G 858
	Unuinkingi	G 685
	Puebla	G 3444
Zaire	Rubona 5	G 4523 (ICA Palmar)
Ethiopia	Roba-1	A 176
	Awash-1	Ex-Rico 23
	Sholla	BAT 338
Uganda	Rubona 5	G 4523 (ICA Palmar)
	G 13671	
Tanzania	Uyole 84	G 1821 (Garbancillo)
Zambia	Carioca	G 4017 (Carioca)
	(Prelease lines:	PAT 10, PAI 78, XAN 76)
Mauritius	BAT 1296	
	BAT 1297	

- Preferably, does the workplan include programme strengthening components such as the development of key methods or training?

Nine subprojects are currently operating on eight topics in eastern Africa, complemented by those in other regions (Table 3). The more advanced subprojects are now working collaboratively with neighbouring countries by sending out a regional nursery or assisting in surveys. We hope that further development of these leadership roles will gradually take the place of many of CIAT's regional staff positions.

Further proposals have been received and, over time, the award of subprojects has become more competitive. Annual requests for renewals are scrutinised by past performance, including the extent to which the subproject is benefiting other countries. The realization of mutual benefits for members is a condition for a sustainable network and ours is continuing to evolve.

Training and Workshops

Since 1986, 20 key scientists, mostly in bean breeding and crop protection, have received specialized training of two to three months at CIAT headquarters. A total of 364 national programme participants are benefiting from locally organized courses including: agronomic research methods (three courses); experimental design, analysis and use of computer packages (two courses); on-farm research methods for extension staff (two courses); training for research technicians in field techniques (four courses); and economic methods (two courses). Several of these short courses were conducted collaboratively with other research centres, particularly CIMMYT and IITA for topics related to farming systems and to grain legumes in general.

Training materials have been extensively distributed to bean researchers, research libraries and universities throughout the region. Audiotutorial units (boxed sets of slides with taped commentary and study guide-book) on six new topics have been developed by CIAT specifically to meet needs in Africa.

Postgraduate training has benefited 15 bean researchers, either for complete scholarship support or for partial support to enable them to conduct more relevant thesis research in their own countries. The first three recipients have already returned to their duties.

Three series of workshops are organised by this and other regional been networks in Africa (Table 4). Besides multidisciplinary regional workshops such as the present meeting, specialized workshops and working group (WG) meetings are held periodically on a pan-African basis, and field monitoring visits for small groups are organized, usually around subproject research. A total of 268 participants from eastern Africa have been registered at workshops since 1986.

Table 4. Bean Research Workshops for Eastern Africa.

	Multidiscipline	Specialized	Monitoring
1986		Beanflies (Arusha)	
1987	Regional (Kampala)	Pathology (Kigali)	Rust
1988		Soil Fertility (Addis)	Breeding
		Nitrogen Fixation (Rubona)	BCMV
		Drought WG (Harare)	
1989		Breeding (Maseru)	CBB
		Intercropping Research Methods (Lilongwe)	
		Cropping Systems WG (Nairobi)	Ascho-chyta
		Soil Fertility WG (Nairobi)	
		Entomology WG (Nairobi)	
1990	Regional (Nairobi)	Virology (Kampala)	

The Role of This Workshop

The general objective of this workshop is to encourage interdisciplinary communication among bean researchers in eastern Africa. As the organisers received more applications for attendance than could be supported, priority was given to papers that focus on recent research results.

Session Two is devoted to reviewing progress in each of the region's subprojects. This is our first attempt at having subproject leaders report back to a regional group of peers. The discussions are intended to assist authors and Steering Committee members alike - their annual meeting is to be held immediately following this workshop. We hope also that informal contacts established here will lead to new collaborators joining particular subprojects, for example by requesting or contributing to a regional nursery. Remember, subproject funds are awarded competitively for the benefit of the region as a whole; objective criticism is useful to all scientists.

A further specific objective is to seek the views of the region on where the future priorities of the regional programme should lie. The final session focuses on this aspect. CIAT's present thinking is that more research emphasis should be given to soil fertility in cropping systems where beans are grown. On the institutional side, we look forward to subprojects taking on leadership roles in the region, in research, in training and through technical advisory visits. We foresee distinctions developing over the next five years between activities managed by scientists of the network as it becomes stronger, complementary activities and those of the regional programme.

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Stability of Yields of Entries in African Bean Yield and Adaptation Nursery (AFBYAN) from 1986 to 1989

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Abstract

Application of the stability analysis of Eberhart and Russell (1966) to yield data from the African Bean Yield Adaptation Nursery showed that for most entries, b values did not differ significantly from unity and deviations from the regression were not significantly greater than zero. For PVA 1272, Mbala Local and Muhinga, the regressions were significantly less than unity and, for G 13671 and Ikinimba they were significantly greater. Deviations from the regression were significantly greater than unity only in the cases of G 2816, Carioca and BAC 76. Stability parameters can be distorted by the composition of the set of entries from which they are derived and must be treated with caution.

Introduction

The use of regression of the yields of individual entries on environmental means to examine variation in yields across a series of environments was first proposed by Yates and Cochrane more then fifty years ago. Finlay and Wilkinson (1963) applied a similar approach but using logarithms rather than actual yields. Eberhart and Russel (1966) were the first to suggest using deviations from regression as well as regressions on environment mean yields as stability parameters. Regression methods have since been developed further by Jinks and others at Birmingham University in the UK (see, Freeman, 1973) to examine the inheritance of stability and have been assessed more recently by Lin *et al.* (1986).

Here, we apply Eberhart and Russell's methods to the analyses of data from AFBYAN I and discuss their implications and the dangers encountered in deriving and interpreting these kinds of stability parameters.

Materials and Methods

The entries, together with their countries of origin and seed and plant types, are shown in Table 1 and the environments in Table 2.

Since entries were not common to all trials, five separate analyses were conducted to derive stability parameters as follows:

1. All environments, omitting Mbala Local (Entry 12), Ikinimba (17), Nain de Kyondo (20) and BAC (= XAN) 76 (25) - parameters for all other entries.

Table 1. Countries Contributing and Characteristics of Entries in AFBYAN 1 between 1986 and 1989.

Entry	Other identity	Country	Seed type Size	Seed type Colour	Plant type
Black Dessie	-	Ethiopia	S	Black	3b
Red Wolaita	-	Ethiopia	S	Red	3b
PVA 1272	-	Rwanda	L	Red/white fleck	1
G 13671	Japones	Rwanda	L	Cream/black fleck	3
G 2816	Garrapato	Rwanda	S	Cream	3
T 3	-	Tanzania	S	Red	3b
T 23	Lyamungu 85	Tanzania	L	Red/white fleck	1
Kabanima	-	Uganda	L	Red/white fleck	1
K 20	-	Uganda	L	Red/white fleck	1
ZPV 292	Gayaza 8	Zambia	L	Purple mottle	3b
Carioca	-	Zambia	S	Brown/cream striped	2b
Mbala local	-	Zambia	L	Yellow-white mixed	4a
Urubonobono	-	Burundi	S	White/black fleck	3
Kirundo	-	Burundi	L	Yellow	3
Calima	-	Burundi	L	Red/cream fleck	1
Rubona 5	-	Rwanda	M	Red/cream fleck	1
Ikinimba	-	Rwanda	M	Black	3
Kilyumukwe	-	Rwanda	L	Purple	2
A 197	-	Rwanda	L	Cream	1
Nain de Kyondo	-	Zaire	S	White	3
Muhinga	-	Zaire	M	White/black striped	3
PVA 880	-	Rwanda	M	Red/white fleck	1
PVA 563	-	Rwanda	M	Red/white fleck	1
G 12470	Peru 14-2	Rwanda	L	Purple/white fleck	1
BAC 76	XAN 76	Rwanda	S	Cream	2

2. Environments 1-11, omitting Ikinimba and BAC 76 - parameters for Mbala Local.

3. All environments except Kisindi (6), omitting Mbala Local, Nain de Kyondo and BAC 76 - parameters for Ikinimba.

4. Environments 1-12, omitting Mbala Local, Ikinimba and BAC 76 - parameters for Nain de Kyondo.

5. All environments except Fifamanor (2), omitting Mbala Local, Ikinimba and Nain de Kyondo - parameters for BAC 76.

Thus parameters from the 21 entries common to all environments are not directly comparable with those of Mbala Local, Ikinimba, Nain de Kyondo and BAC 76, though the different estimates did not diverge substantially from each other.

Figure 1. PVA 563 - regression of individual entry mean seed yields on environment means (kg/ha).

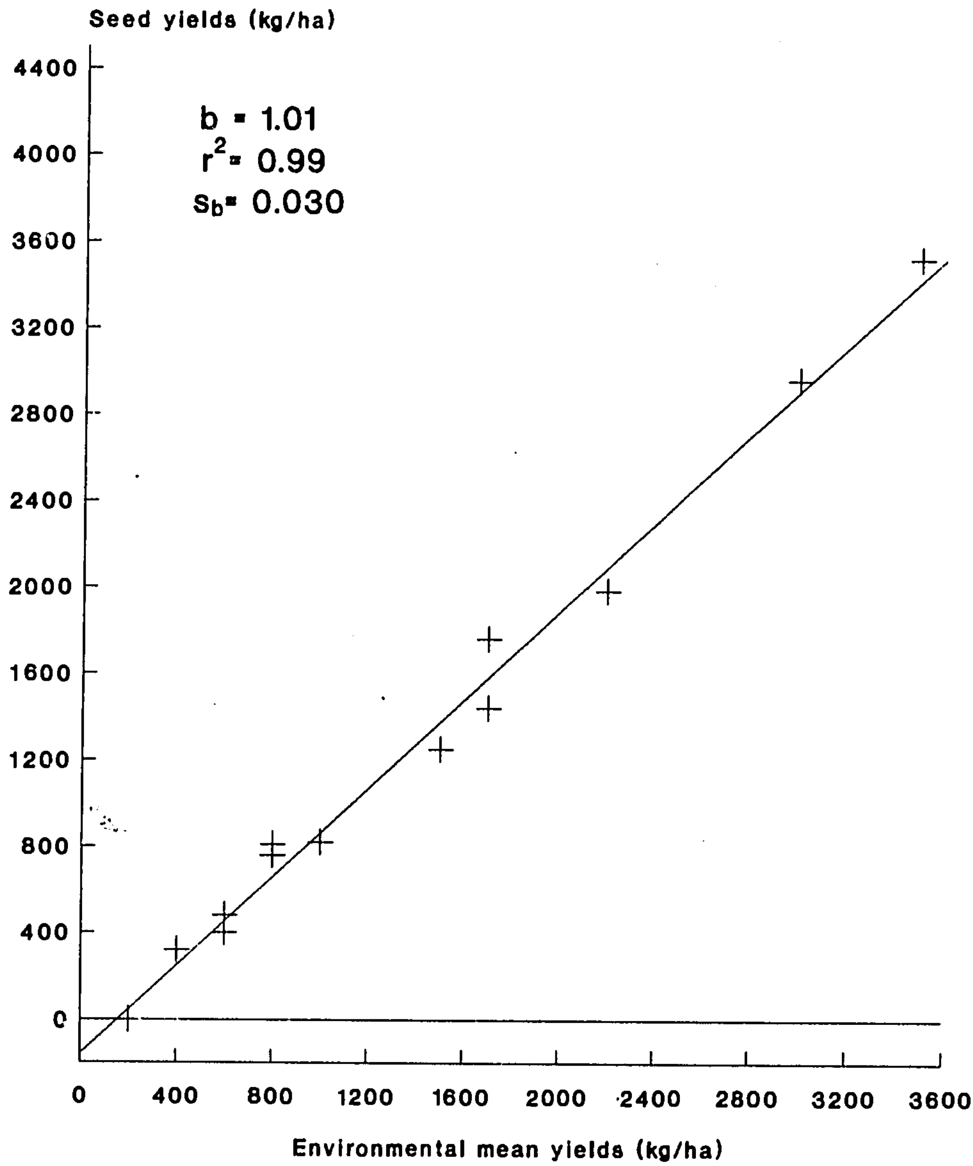


Figure 2. PVA 1272 - regression of individual entry mean seed yields on environment means (kg/ha).

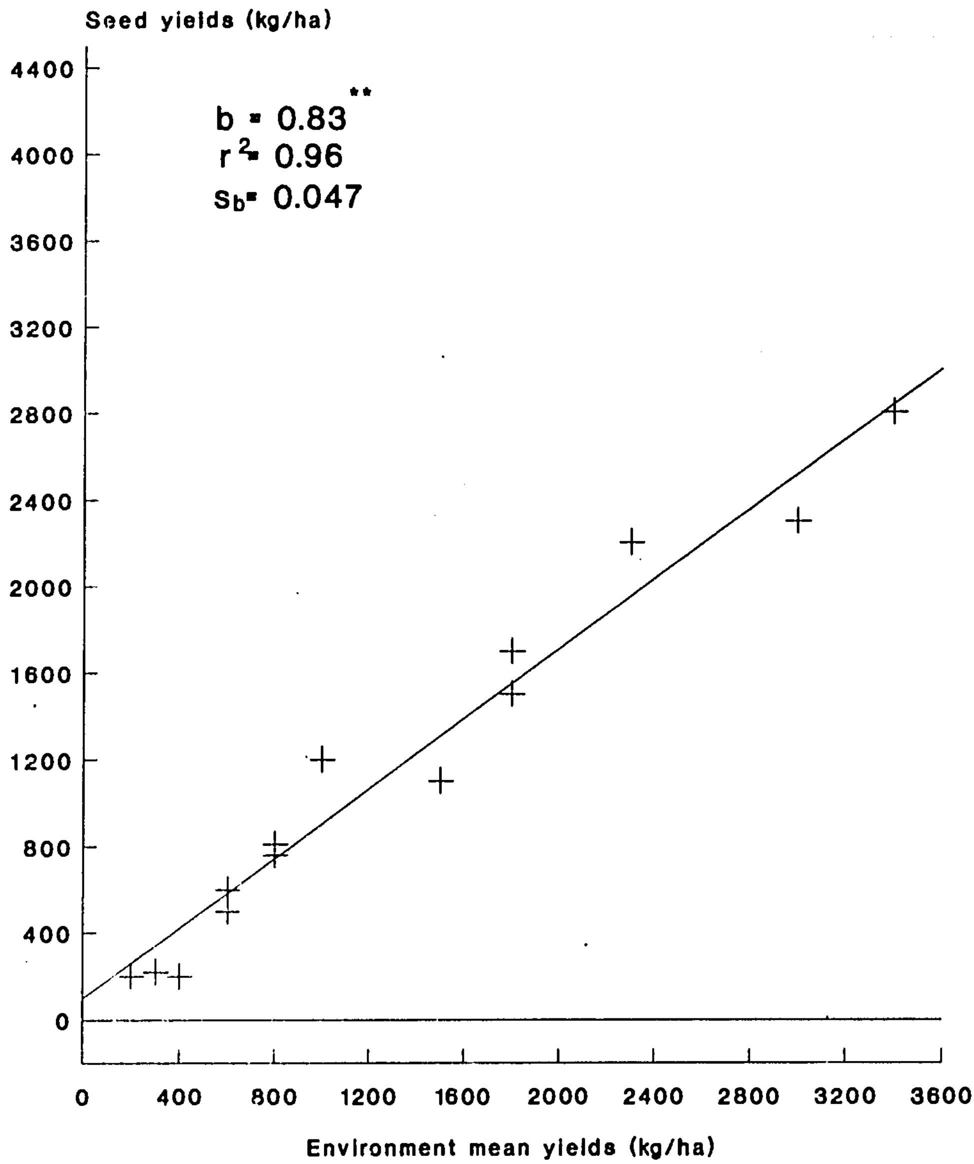


Table 2. Environments in which AFBYAN I was Grown between 1986 and 1989.

Location	Season	Country	Sowing date
Melkassa	1987	Ethiopia	30 June
Fifamanor	1988	Madagascar	1 March
Kachwekano	1987F	Uganda	25 April
Kawanda	1986S	Uganda	mid October
Kawanda	1987F	Uganda	9 April
Kisindi	1987F	Uganda	March
Rubona	1987F	Rwanda	8 October
Mulungu	1987F	Zaire	October
Msekera	1987	Zambia	8 January
Msekera	1988	Zambia	10 January
Mbala	1988	Zambia	13 January
Selian	1989	Tanzania	30 March
Selian	1989	Tanzania	4 April
Irente	1989F	Tanzania	15 April

The significance of the divergence of regression coefficients (b) of individual entries from unity were determined by comparison with the standard error of their deviations from regression by means of 't' tests:

$$t = \frac{b-1}{s_b}$$

The significance of their deviations from regression were determined by comparison of their deviation mean squares with the pooled error mean square by means of 'F' tests.

Results and Discussion

The regression coefficients, coefficients of determination, (r^2) and standard errors of deviations from regression (s_b) for the 25 entries are shown in the Table 3.

Various reponses were exhibited among the 25 entries in AFBYAN I. Most had b values not significantly different from unity and deviations from regression not significantly greater than zero - for example, PVA 563 (Figure 1). Three entries (PVA 1272, Mbala Local and Muhinga), exhibited b values significantly smaller than unity - for example, PVA 1272 (Figure 2). Two (G 13671 and Ikinimba) had b values greater than unity - for example Ikinimba (Figure 3) - and three had deviations from regression greater than zero (G 2816, Carioca abnd BAC 76) - for example, G 2816 and Carioca (Figures 4 and 5).

Table 3. Stability Parameters for Seed Yields (kg/ha) of 25 Entries in AFBYAN I grown between 1986 and 1989.

Entries	b	r^2	s_b
Black Dessie	1.04	0.94	0.074
Red Wolaita	0.94	0.95	0.064
PVA 1272	0.83**	0.96	0.047
G 13671	1.20*	0.95	0.083
G 2816	1.06	0.75	0.177***
T 3	0.91	0.92	0.075
T 23	0.89	0.93	0.073
Kabanima	0.95	0.95	0.064
K 20	1.07	0.90	0.101
ZPV 292	1.08	0.94	0.079
Carioca	1.25	0.88	0.132**
Mbala Local	0.81*	0.92	0.080
Urubonobono	1.13	0.96	0.070
Kirundo	0.99	0.96	0.059
Calima	0.85	0.92	0.073
Rubona 5	1.11	0.96	0.069
Ikinimba	1.33**	0.94	0.105
Kilyumukwe	0.96	0.93	0.078
A 197	0.90	0.96	0.056
Nain de Kiyondo	0.68*	0.76	0.120
Muhinga	0.85**	0.98	0.038
PVA 880	0.92	0.94	0.066
PVA 563	1.01	0.99	0.030
G 12470	1.04	0.95	0.066
BAC (=XAN) 76	1.22	0.92	0.112*

There are various considerations in the interpretation of such data.

First, the magnitudes of the regressions and the deviations from them will almost certainly change with changes in the sets of genotypes and environments from which they are derived. To be meaningful, the sets of both genotypes and environments should sample the total genotypic and environmental variability to be characterized. This is rarely achieved.

Instead, multilocation tests usually involve small numbers of entries that have already been intensively selected for particular situations and therefore comprise a very small proportion of the total available genotypic variability.

Moreover, environment mean yields are likely to be heavily weighted by the response of entries of similar history, therefore responding in similar manner to the environments to which they are being exposed. In this situation, the regressions of the entries different in response will deviate (positively and negatively) from unity and their deviations from regression will be greater than those of the other entries. But they can not be considered less stable: their response (or stability) merely differs to that of the entries that predominate.

Figure 3. Ikinimba - regression of individual entry mean seed yields on environment means (kg/ha).

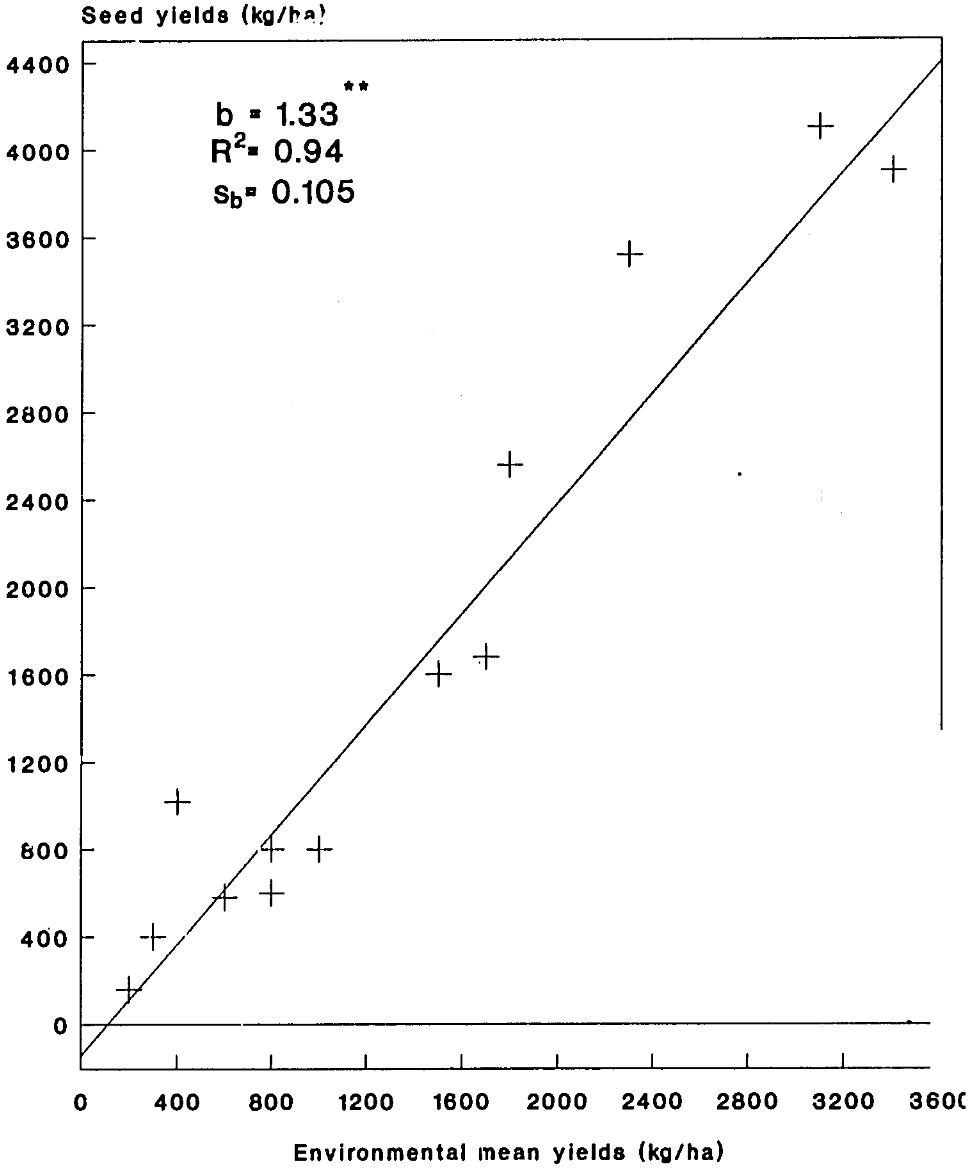


Figure 4. G 2816 - regression of individual entry mean seed yields on environment means (kg/ha).

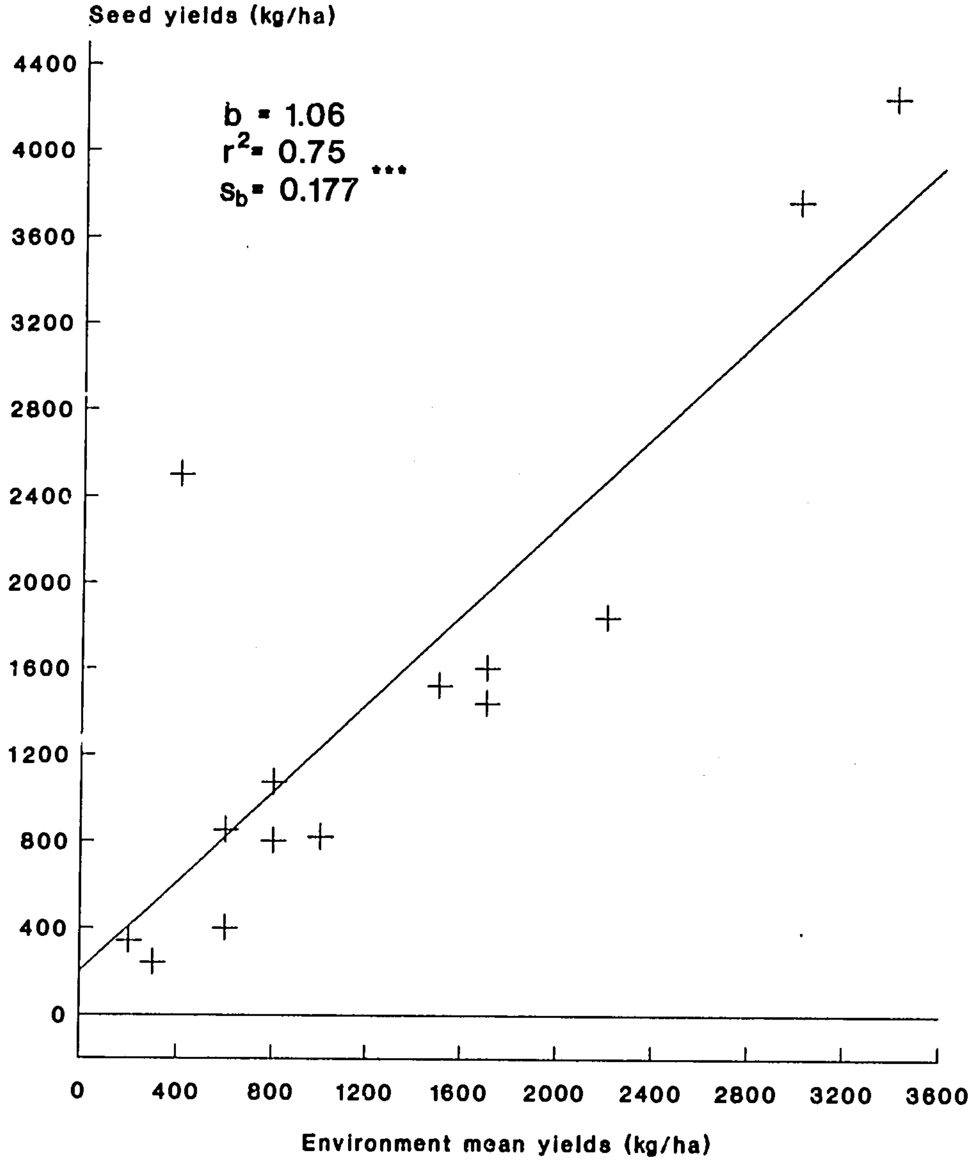
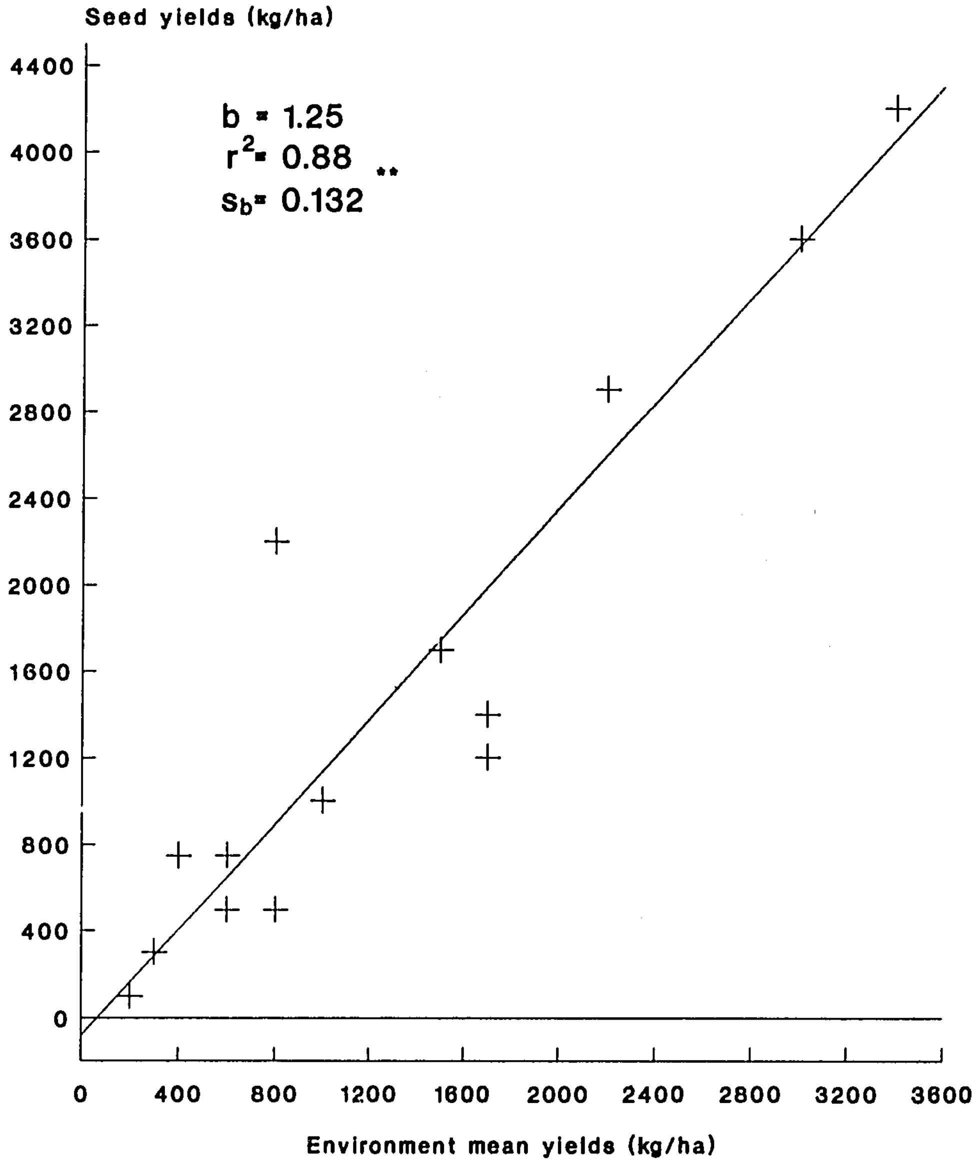


Figure 5. Carioca - regression of individual entry mean seed yields on environment means (kg/ha).



With regard to environments, spatial variability can be accommodated by selection of appropriate locations but sets of entries are changed from season to season as new entries from a previous stage replace poor performers that are discontinued and superior performers that are promoted. Environment mean yields are therefore composed differently from season to season, so cannot strictly be used to characterize seasonal responses.

In the case of AFBYAN I, the environments are spatially diverse but temporally too few to provide an adequate sample of seasons. The entries were contributed by national programmes but ten of the 25 are determinate and eight of these are Calima types and, although the histories of many of them are not clear, probably of similar origin. The environmental index must be heavily weighted by their reactions to environments, so it is not surprising that only one of them (PVA 1272) shows any deviation from the index. Also, because of the weighting we cannot say that those that do show deviations are less stable, but merely that they differ in their response to environments.

However, the mere differences and similarities in response are of interest. The similar behaviour of most of the determinate types is remarkable in its confirmation of what would be expected and underlines the need for greater variability. Also remarkable is that PVA 1272, although determinate and with a Calima type seed, does appear to perform relatively better in poorer yielding environments, thereby demonstrating the existence of greater variability even among determinate types.

All classes of responses are represented among the indeterminate types, which differ in the slopes of their regression lines and their deviations from regression. This too would be expected since there is the opportunity for much greater variation in plant type and also in response to environmental changes, than among determinate plant types.

Stability analysis is a step aheaa of conventional analysis of variance in partitioning the interactions sums of squares into linear and non-linear components. In so doing it helps us to detect aberrant genotypes and may lead to the identification of some of the factors influencing yields.

For example, the significant deviations from regression of G 2816 result mainly from its superiority at Mulungu. One of the features that distinguished Mulungu from other environments was heavy beanfly damage. This would therefore lead us to explore the beanfly resistance of G 2816. In contrast, the deviation from regression of Carioca results mainly from its superiority at Kawanda in the first season of 1987. Unfortunately, we have neither sufficient environmental nor other plant character data from this trial to even guess at the reasons for the aberrant behaviour in this case but at least there is some indication of an environmental feature causing a major differential response that should be sought in further trials with Carioca in this environment.

In order to make further progress in yield improvement, we do need more complete understanding of the environmental factors affecting yields and the ways in which they interact with plant growth and development. Stability analysis merely enables us to characterize interactions, it does not enable the identification of the factors involved. There are many possible approaches. We are presently examining plant character and environmental data from the AFBYAN series with a view to elucidating the main factors contributing to g x e interactions in beans (Smithson and Grisley, in press).

Acknowledgements

The efforts of all national and international programme scientific and technical staff who have collaborated in the conduct of the AFBYAN are gratefully acknowledged.

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Regional Collaborative Research Project on Common Bacterial Blight, Xanthomonas campestris pv. phaseoli (Smith) Dye, of Common Bean (Phaseolus vulgaris L.)

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Abstract

The work carried out from 1987 to 1989 is described. It included identification of suitable methodologies for screening for resistance to common bacterial blight (CBB), breeding for resistance to CBB, formation of the East African Regional Common Bacterial Blight Nursery (EARCBBN) and evaluation of various chemicals for its control. The prospects of producing disease free seed in dry areas were investigated and future plans are outlined.

CBB scores were maximum where spreaders were sown in a box formation, one to two weeks before and around every 6 to 8 test lines. The best sources of CBB resistance were G 4399, XAN 159, XAN 112, BAT 1500, G 5448, GN Jules, GN Tara and PI 247262. Copper chemicals reduced the severity of CBB but none completely eliminated it. The chemical treatments produced significantly heavier yields than the control. Dry area seed production with furrow irrigation may be the best solution to the seed production problems of Uganda and probably other parts of Africa.

Justification

Common bacterial blight caused by *Xanthomonas campestris* pv. *phaseoli* (Smith) Dye (Xcp) is one of the five most important diseases of bean in Uganda (Leakey, 1963; Sengooba, 1985). The other four are: angular leaf spot (*Phaeoisariopsis griseola*), rust (*Uromyces phaseoli* var. *phaseoli*) in low altitude areas; and halo blight (*Pseudomonas syringae* pv. *phaseolicola*) and ascochyta blight (*Phoma exigua* var. *diverspora*) in the highlands. Of these, angular leaf spot and common bacterial blight (CBB) are most prevalent (Sengooba, 1985).

CBB is also of serious concern in other parts of eastern Africa. It is regarded as a major problem of bean in Ethiopia (Habtu, 1987), Kenya (Mukunya *et al.*, 1981) and Burundi (Perreaux *et al.*, 1986). It is also prevalent in low altitude areas of Tanzania.

Although CBB was identified as an important disease of bean in Uganda in the early 1960s (Leakey, 1963), no particular attention was given to it. Rather, breeding programmes focused on anthracnose and later, angular leaf spot (Sengooba, 1987). Because of lack of resistance to the disease in commercially acceptable cultivars and landraces, the Uganda seed multiplication project faced a problem with bean seed in the early 1980s. There was an outbreak of CBB at their main seed multiplication farm and bean seed multiplication was abandoned.

Bean cultivars with resistance to CBB have been developed in temperate countries. They include XAN 159, XAN 112, the Nebraska selections (GN Jules, GN Tara, GN Nebraska selection 27, PI 207262) (Coyne and Schuster, 1969; Coyne *et al.*, 1963). These cultivars are, however, poorly adapted to the tropics and hence appear susceptible (Webster *et al.*, 1983). There is therefore need to develop resistant bean cultivars well adapted within the region itself. Materials developed by CIAT that show resistance to CBB require study to develop an integrated approach to controlling the disease.

The project is handled on a regional level because of the importance and widespread nature of CBB in the region. Countries included in the collaboration are Ethiopia, Kenya, Burundi, Rwanda, Zaire and Tanzania. Since these countries share ecological zones with Uganda, results and materials with resistance can be quickly distributed to them, thus reducing duplication of effort. The project was approved in 1987.

Objectives

1) To identify suitable methodologies for evaluation of bean germplasm for resistance to CBB under field and/or greenhouse conditions.

2) To control CBB of bean through breeding.

3) To develop a CBB nursery for eastern Africa.

4) To study the variation and host range of CBB in eastern Africa.

5) To control CBB using chemicals and dry areas for seed production.

6) To study the symptomatology of CBB on bean.

7) If necessary, to study the inheritance and heritability of resistance to CBB to develop breeding methods.

The study of symptomatology (No. 6) was removed. Studies of the seed transmission and survival of the pathogen were started in 1990.

Results

The progress with each objective will be described in the above order. In the area of Uganda where the trials have been conducted there are two cropping seasons. The first, which commences around March, is designated A and the second, which begins in September/October, is designated B.

Identification of Suitable Methodologies for Evaluation of Bean Germplasm for Resistance to Common Bacterial Blight

Three trials were sown in two seasons (1987 and 1988) to determine the time of sowing (relative to a set test lines), frequency and arrangement of spreaders to obtain uniform and maximum disease pressure. All trials were split-split plots with the same twelve test lines as main plots and the spreader treatments as sub-plots, replicated three times. In all trials, the spreaders were inoculated and CBB scored on scales of 1 to 9 at flowering (R6), podding (R8) and physiological maturity (R9).

In the time of sowing trial, spreaders were sown 1, 2 and 3 weeks before the test lines. In the frequency and arrangement trials, spreaders were sown either in single or double rows every 2, 6, 8 and 10 test lines. With the double rows, spreaders were also sown across the ends of the test lines after a path of 60 cm, to produce a box formation.

CBB reactions were greater in 1988 than in 1987. In all trials, there were significant differences among test lines, spreader treatments and stages of scoring (Table 1). CBB scores were significantly larger at R9 than at R6 or R8, because pod reactions were also assessed in the later score or due to the increase in disease with plant age (Tables 2-4). Although differences among test lines were significant, none showed high resistance to CBB. In the time of of sowing trial, for example, reactions at R9 ranged between 4.11 and 4.58 in 1987 and 6.50 and 8.67 in 1988 (Table 2). In both seasons and overall Kanyebwa, Kampulike and K20, all locally cultivated, had larger scores than other entries. There were also significant interactions of stage of scoring with test lines and spreader treatments in all trials except the time of sowing trial in 1988.

Table.1. Mean squares from analysis of variance of CBB scores in time of sowing and frequency and arrangement of spreaders trials in 1987 and 1988.

Source	Time of sowing			Frequency and arrangement				
	df	Mean squares		df	Mean squares			
		1987	1988		1987[a]	1988[a]	1987[b]	1988[b]
Reps	2	0.11	3.36	2	1.55	1.38	0.03	2.45
Test lines (TL)	11	15.30**	11.42**	11	23.48**	20.01**	10.65**	11.59**
Error (a)	22	0.49	0.79	22	0.84	0.62	0.63	0.66
Sub-plots (SP)[c]	2	14.00**	14.56**	3	10.61**	11.48**	10.02**	14.34**
TL x SP	22	0.68	1.28	33	8.76*	1.72	1.06	0.76
Error (b)	48	0.41	1.00	72	0.97	0.38	0.04	0.62
Stage of score (SC)	2	193.61**	193.06**	2	363.27**	366.04**	357.32**	386.17**
TL x SC	22	11.24**	0.66	22	4.17**	4.77**	4.24**	3.19**
SP x SC	4	3.00**	2.92**	6	12.99**	11.89**	8.29**	8.70**
TL x SP x SC	44	0.45	0.65	66	0.62	0.95	0.29	0.51
Error (c)	144	0.27	0.52	192	0.59	0.54	0.30	0.44

* and ** = significant at P_b = 0.05 and 0.01, respectively,
[a] spreaders in single rows; [b] spreaders in box formation;
[c] time of sowing, frequency and arrangement of spreaders

In the time of sowing trial, differences among entries were small at R6 but increased at R7 and R9 (Table 2). Disease scores on the test lines were significantly greater when the test lines were sown 1 and 2 weeks after the spreaders than when they were sown 3 weeks later (Table 3), the increase being most obvious at R9 accounting for the significant interaction between time of planting and stage of scoring. Sowing spreaders 1 or 2 weeks before the test lines and scoring at R9, therefore, appear to produce the maximum disease pressure.

Table 2. Mean Disease Scores at R6, R8 and R9 for Test Lines in 1987 & 1988.

Test lines	1987				1988				Mean
	R6	R7	R8	Mean	R6	R7	R8	Mean	
CATU	3.00	3.43	4.22	3.55	3.00	4.08	7.00	4.69	4.12
BAC 36	3.00	3.49	4.48	3.67	3.00	4.25	6.83	4.69	4.18
Carioca	3.00	3.52	4.23	3.58	3.00	4.33	7.00	4.78	4.18
BAT 1220	3.00	3.56	4.23	3.60	3.00	4.50	7.00	4.83	4.21
K20	3.00	3.99	4.43	3.81	3.00	6.00	7.92	5.64	4.72
Kanyebwa	3.00	4.09	4.58	3.89	3.00	6.42	8.67	6.03	4.96
B/Haricot	3.00	3.43	4.24	3.56	3.00	4.08	7.08	4.72	4.41
W/Haricot	3.00	3.41	4.28	3.56	3.00	4.08	7.25	4.78	4.17
A 140	3.03	3.33	4.18	3.51	3.08	3.83	6.83	4.58	4.04
A 83	3.00	3.43	4.11	3.51	3.00	4.08	6.50	4.53	4.02
A 162	3.00	3.46	4.12	3.53	3.00	4.17	6.58	4.58	4.05
Kampulike	3.03	4.06	4.39	3.83	3.08	6.25	7.83	5.72	4.77
S.E.±		0.93[a]		0.12[b]		1.65[a]		0.16[b]	0.18[d]
C.V. (%)		9.3				12.6			
Mean	3.00	3.60	4.29	3.63	3.01	4.67	7.21	4.96	4.32
S.E +		0.35[c]				0.46[c]			0.99[e]

[a] test lines x stage of scoring; [b] test lines; [c] stage of scoring;
[d] test lines combined across years; [e] years

In both years, whether spreaders were in single rows or box formation, CBB scores were significantly larger where spreaders were sown every 2 test lines than where they were every 10 test lines (Table 4), but the differences were slight. It is concluded that maximum CBB disease pressure can be obtained by sowing spreaders 1 to 2 weeks before every 6-8 test lines in single rows or in box formation.

Breeding for Resistance to Common Bacterial Blight

XAN 159, XAN 112, G 4399, PI 207262, GN Jules, GN Tara, XNA 93 and GN Nebraska No. 1 Sel. 27 were found resistant in International CBB Nurseries at Kawanda in 1987 and 1988.

Table 3. Mean Disease Scores at R6, R8 and R9 for Test Lines with Spreaders Sown 1, 2 and 3 Weeks Previously in 1987 and 1988.

Time of sowing[a]	1987 R6	1987 R7	1987 R8	1987 Mean	1988 R6	1988 R7	1988 R8	1988 Mean	Mean
1	3.04	4.58	5.10	4.24	3.33	4.94	5.97	4.75	4.50
2	3.00	4.52	4.98	4.17	3.09	4.42	6.14	4.55	4.36
3	3.02	4.51	4.58	4.04	3.00	4.69	5.42	4.37	4.21
S.E.±		0.17[b]		0.06[c]		0.12[b]		0.41[c]	0.26[e]
C.V. (%)		24.6				16.2			
Mean	3.02	4.54	4.89	4.15	3.14	4.68	5.84	4.55	
S.E.±		0.06[d]				6.10[d]			0.24[f]

[a] delay in sowing of test lines after spreaders (weeks);
[b] time of planting x stage of scoring; [c] time of planting;
[d] stage of scoring; [e] time of planting combined across years;
[f] years

At Kawanda in 1989A, the donor parents, G 4399 and XAN 112, were crossed with the recurrent parents, Kanyebwa, Rubona 5, K20, ZPV 292 and Red Wolaita. Success ranged up to 40%. In 1989B, F_1 populations were grown alongside their parents. Plant type and colour were used to detect failed crosses. At R6, black root appeared in the nursery and by R9 the F_1s with G 4399 and XNA 112 as parents had been completely killed.

Further crosses were made at Bukalasa in 1989B. GN Nebraska No. 1 Sel. 27, GN Jules, GN Tara, XAN 159, XAN 112 and PI 207262 were the donor parents with the same recurrent parents as in 1989A and Namunye. Successful crosses amounted to 60%. F_1s of crosses with XAN 112 and XAN 159 as parents were lost due to black root. The other F_1s were harvested as single pods and a single seed descent/pedigree selection system will be used to advance generations, accompanied by backcrossing.

In the International CBB Nursery 1989-1990, black root was observed in XAN 159 and XAN 112. In view of the problems with black root, in future, materials without the I gene will be used as donor parents, but this greatly reduces the number of donor parents in use.

Another crossing block, with GN Jules, GN Tara, PI 207262, GN Nebraska No. 1 Sel. 27, XAN 6, IAPAR 16, ICA Linea-64, Amanda (75-20), G 09857, MX 259-8 as donor parents and the same recurrent parents that were used in 1989, has been established at Kawanda.

Table 4. Mean Disease Scores at R6, R8 and R9 for Test Lines with Spreaders in Single Rows at Four Frequencies in 1987 and 1988.

Frequency[a]	1987				1988				Mean
	R6	R8	R9	Mean	R6	R8	R9	Mean	
2	4.00	4.62	5.35	4.67	3.54	4.20	6.06	4.60	4.63
6	3.99	4.67	5.26	4.64	3.05	4.40	6.23	4.56	4.60
8	4.00	4.55	5.22	4.59	3.19	4.18	6.19	4.52	4.55
10	3.95	4.54	5.19	4.56	2.81	4.10	6.32	4.41	4.45
S.E.±		0.15[b]		0.16[c]		0.04[b]		0.08[c]	
C.V. (%)		17.3				16.2			
Mean	3.98	4.59	5.25	4.61	3.15	4.04	6.20	4.56	
S.E.±		0.06[d]				1.05[d]			0.22[e]

[a] number of test lines between each pair of spreader rows;
[b] frequency x stage of scoring; [c] frequency; [d] stage of scoring;
[e] years

The Development of a Common Bacterial Blight Nursery within Eastern Africa

The aim of this study is to identify bean materials resistant to CBB in the region to compose the East African Regional Common Bacterial Blight Nursery (EARCBBN). The EARCBBN will serve for NPs in the region to identify resistant lines for parents in breeding programmes.

In 1989A, 118 local collections and introductions that had previously shown resistant reactions to CBB, together with others of intermediate and susceptible reactions for comparison, were grown at Kawanda. In 1989, 30 lines received from Ethiopia and six Burundi lines that had shown resistance to CBB in Rwanda and Burundi were added to this nursery, which was sown at Bukalasa.

Unfortunately most of the initial 118 lines have been affected by black root and may have to be rejected. It is expected to obtain additional resistant materials from Kenya, Tanzania, Zambia and Zaire before the end of the year.

Variation in Pathogenicity of Xanthomonas campestris pv. phaseoli (Xcp)

Detailed studies of variation in Xcp have now started at Kawanda on collections from various ecological zones of Uganda. Several common bean (*P. vulgaris* L.) and tepary bean (*P. acutifolius*) materials with differing levels of resistance to CBB are being used. Bacteriophages will also be used to differentiate isolates. At a later stage these studies will be extended, initially to Ethiopia and then to Tanzania and Kenya.

Control of CBB of beans

Chemical Control

Seven chemicals were tested in a randomized complete block experiment with four replicates at Kawanda for three seasons from 1987B to 1989A. The plot size was 4.8 x 5 m. The chemicals and their rates in 5 l of water per plot (in parenthesis) were as follows: cupric sulphate (2.5 g), cuprous oxide (2.0 g), cupric nitrate (2.5 g), copper chloride (3.0 g) and streptomycin sulphate (5%). The solutions were applied as foliar sprays at two weekly intervals until physiological maturity. Five litres of water were applied to the control plots. Severity was assessed using a scale of 1 to 9 at three stages (R6, R7 and R8). Total and clean yields were recorded.

In 1988A and 1988B, CBB scores at R7 and R8 were reduced significantly (P = 0.05) by the application of chemicals (Table 5). In 1989A none of the chemicals reduced CBB scores at R7, although five of them did so at R8. Differences among chemical treatments were not significant. The disease increase rate was reduced by all the chemicals although differences among treatments were not significant.

The total and clean seed yields were larger in most cases where chemicals were applied but the increases were significant only with cupric carbonate and sulphate and cuprous oxide in 1988A.

In 1989B, cupric carbonate and cupric sulphate were combined with chemicals previously recommended as seed disinfectants for bacterial diseases to examine the prospects of better control. The seed dressings were mercuric chloride, alcohol (70%) and streptomycin. They were applied to three cultivars (Kanyebwa, K20 and Ikinimba) using a split plot design with cultivars as main plots and chemicals as sub-plots.

Table 5. CBB Scores at R7 and R8 of Treatments in Chemical Evaluation Study at Kawanda in 1988A, 1988B and 1989A.

Treatment	1988A		1988B		1989A		Mean	
	R7	R8	R7	R8	R7	R8	R7	R8
Cupric sulphate	4.75a	5.25a	2.75a	2.75a	2.85a	4.25a	3.45	4.08
Cuprous oxide	4.75a	5.50a	2.75a	3.75a	3.61a	3.96a	4.29	4.40
Cupric carbonate	4.75a	5.50a	2.75a	3.75a	2.76a	4.07a	3.42	4.41
Cupric chloride	4.00a	4.75a	3.00a	4.00a	2.72a	4.26ab	3.24	4.34
Cupric nitrate	4.25a	5.00a	2.75a	3.75a	3.20a	4.32ab	3.43	4.37
Copper oxychloride	4.00a	4.75a	3.00a	4.00a	3.20a	4.00a	3.42	4.25
Streptomycin + copper oxychloride	4.00a	5.25a	3.50a	4.50a	3.22a	3.96a	3.57	4.61
Water alone	6.00b	7.75b	5.50b	7.25b	3.50a	4.68b	5.50	6.56
S.E.±	0.365	0.352	0.364	0.359	0.968	0.145		
Mean	4.56	5.47	3.28	4.34	3.00	4.20		
C.V. (%)	19.5	13.5	22.0	16.2	24.4	13.7		

Table 6. Means of Clean and Total Yields During Seasons 1988A, 1988B & 1989A.

Treatment	Yields of middle 5 rows (g)				Yield of 5 plants (g)	
	1988A		1988B		1989A	
	Total	Clean	Total	Clean	Total	Clean
Cupric sulphate	940ab	793ab	930a	588a	100.0a	85.7a
Cuprous oxide	910ab	810ab	785a	510a	77.3a	70.9a
Cupric carbonate	1010a	875a	910a	660a	90.5a	73.0a
Cupric chloride	690bc	608bc	858a	515a	63.0a	54.8a
Cupric nitrate	870abc	763ab	845a	410a	79.4a	66.1a
Copper oxychloride	700bc	595bc	640a	475a	79.4a	66.4a
Streptomycin + copper oxychloride	764abc	750abc	650a	515a	75.2a	66.3a
Water alone	602bc	480c	700a	400	73.0a	57.7a
S.E.±	87.7	80.8	117.5	95.4	8.72	7.05
Mean	811	601	790	509	79.7	67.6
C.V.(%)	21.6	23.2	30.0	38.6	21.9	20.9

Note: scores in the same column followed by the same letter are not significantly different at P = 0.05 according to Duncan's Multiple Range Test.

All the chemicals significantly reduced CBB scores in 1989B and some of them in 1989A but the differences among chemicals were not significant (Table 7).

In 1989B, there were no differences among treatments in total yield but all combinations of cupric carbonate with seed disinfectants produced significantly greater clean yields (P = 0.05) than the control. Fewer pods were infected where cupric carbonate was applied, so the improvement in clean seed yields may have arisen from cupric carbonate reducing the spread of CBB to the pods.

Seed Production in Dry Areas

None of the chemical treatments applied would be useful for clean seed production, because as little as 0.5% CBB infected seed is sufficient to cause epidemics when environmental conditions (high temperature and high humidity plus rain splash) are favourable. Dry areas may be more suitable for producing clean seed. The prospects of dry areas for producing clean seed were examined in off-seasons in 1988 and 1989 at Mobuku, which is in a dry rain shadow area but with furrow irrigation facilities. Five landraces were sown in randomized complete block designs with four replicates. CBB was scored on a scale of 1-9 at R8.

Table 7. CBB Scores at R8 of Treatments in the Chemical Evaluation Study using Combinations of Two Foliar Sprays, Two Seed Dressings and Three Cultivars of Bean in 1989a and 1989b.

Treatment	1988A	1988B	1989A
Mercuric chloride + cupric sulphate	4.40abc	5.60a	5.05
Mercuric chloride + cupric carbonate	4.20ab	5.60a	4.90
Alcohol + cupric sulphate	4.50abc	5.80a	5.15
Alcohol + cupric carbonate	4.50abc	5.60a	5.05
Streptomycin + cupric carbonate	4.10a	5.40a	4.75
Alcohol	4.30abc	5.80a	5.05
Streptomycin	4.60c	5.70a	5.15
Mercuric chloride	4.20ab	5.90a	5.05
Water alone	4.60c	7.50b	6.05
S.E.$\pm$	0.127	0.547	
Mean	4.38	5.88	
C.V.(%)	10.1	15.9	

Note: scores in the same column followed by the same letter are not significantly different at P = 0.05 according to Duncan's Multiple Range Test

In 1988 and the first off-season in 1989, CBB scores were very low (maximum of 2). In the second off-season 1989, rains continued and CBB scores at R7 were large (mean of 6). These results support the use of dry conditions for clean seed production and the intensification of the search for suitable situations.

It is concluded that chemicals alone are inadequate for clean seed production but that it is possible to produce clean seed in dry situations with the aid of furrow irrigation.

Future Work

Future work on CBB will emphasize the following objectives:-

1. To incorporate resistance to CBB into landraces and establish quantitative differences among the different resistant sources with respect to susceptibility to CBB.

2. To study the interrelationships between resistance to CBB and other quality traits in common bean.

3. To identify the stages where selection in segregating populations is reliable.

4. To establish the relationships between seedling and adult plant resistance and compare greenhouse and growth chamber methods for predicting field resistance.

5. To study pathogenic variation in Xcp in eastern Africa.

6. To determine whether there are differences among genotypes in their ability to transmit CBB with a view to selecting for low seed transmission efficiency.

7. To study the survival of CBB on weeds and non-hosts and in soils.

8. To continue identifying entries for the EARCBBN.

It is expected that all the objectives will be accomplished by December 1992.

Work Plan for 1990

Pathology

1. Studies of the variation in Xcp will continue in 1990, mainly in the screenhouse. Collection of isolates to be continued in Uganda in seasons A and B.

2. Seed transmission studies in the laboratory, screenhouse and field.

3. Studies of the survival of Xcp to be started in 1990A and continue throughout the year.

4. The EARCBBN to be screened at Kawanda. The nursery is to be modified. Those entries that were affected by black root will be omitted and other entries added.

Breeding

1. Observations of F_1 populations involving reciprocal crosses where donor parents having the I-gene were used as males.

2. More crosses involving new donor parents and recurrent parents from other collaborating countries.

3. To determine whether different mechanisms confer resistance in different plant parts.

4. Studies of the seed resistance of donor parents.

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Progress in Studies of Phoma Blight of Common Bean in Eastern Africa

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Abstract

Progress is reported in the breeding and pathology of Phoma blight (PB) (Phoma exigua var. diversispora) of bean, initiated in 1987. Extensive screening has been conducted at Kachwekano in south-western Uganda. Disease pressure varied across seasons. Resistance was very rare among bush bean genotypes but was fairly stable in G 4603, AND 556 and G 17098. More resistants were found among climbers, the best being G 12582, G 10747 and VRA 81051. A number of P. coccineus lines exhibited very good resistance. Crosses were started in 1989 to improve local genotypes and for inheritance studies. A regional nursery has been established.

PB tended to be more severe in beans in association with maize than in pure stand, especially when maize was between rows of beans, but the differences were not always significant. Genotype X cropping system interactions were not significant. Fungicidal application significantly reduced PB infection. Roguing also tended to do so but the differences were not significant. Cleaning infected bean seeds by sowing in a disease free area proved promising.

Introduction

Phoma blight (PB) caused by *Phoma exigua* var *diversispora* (CIAT, 1988 occurs in many bean growing areas of the world. In eastern Africa, PB is c notable importance under cool, humid conditions, which tend to prevail at hig altitudes. Areas where PB is a constraint to bean production in easter Africa include: the highlands of south-western Uganda, the slopes of Moun Elgon, the highlands of Kenya, the island of Madagascar and almost the whol of Rwanda and Burundi (van Schoonhoven, 1980; personal communications) encompassing a large and important bean production zone.

A regional sub-project was initiated in 1987 to investigate the breedin and pathology aspects of PB in eastern Africa, where there had formerly bee very little work on this disease The regional sub-project was expected: t facilitate access to a wide range of variation in terms of germplasm environments and pathotypes; and to contribute to faster progress an sustainable results.

Though measures for the control of PB have been documented (Schwartz an Galvez, 1980), these have not been evaluated for their effectiveness an applicability under eastern Africa conditions. Attempts to breed for P resistance in bean have had limited success. CIAT (1987, 1988) reporte resistance in *P. vulgaris* climbers but not in bush bean. Following extensiv selection and intensive crossing programmes, CIAT established a PB nursery i 1987. The genotypes in this nursery will be useful in eastern Africa only i they are also resistant there.

Since the occurrence of PB fluctuates violently across seasons, sometimes causing heavy losses, studies of the epidemiology and control of PB are necessary. Because intercropping has been reported to reduce disease (van Rheenen *et al.*, 1981; Altieri and Liebman, 1986), PB levels in bean in pure stands and in association with maize have been compared.

Most of the field trials described were conducted at Kachwekano in two seasons, the first (designated A) starting in March and the second (B) in October/November.

Objectives

The sub-project was initiated with the following objectives:

1. To screen a wide range of germplasm locally, to identify genotypes resistant to PB.

2. To compose a regional PB nursery (EARPBN) to study resistance across sites and exploit the pathogenic variation and host-pathogen interactions that occur in the region.

3. To develop resistant genotypes through hybridization.

4. To study the inheritance of resistance so as to identify suitable breeding strategies.

5. To study the epidemiology of PB in pure stand and in association with maize.

6. To develop integrated control measures.

Results

A number of studies have been conducted in accordance with these objectives.

Germplasm screening for resistance to PB

Some 1000 lines have been screened for PB at Kachwekano in southwestern Uganda (Table 1). Three metre rows, replicated at least twice were used, except in the case of the VEF of 86 and other CIAT accessions, where there was no replication. A spreader row was planted after every entry. In 1987 and 1988, some trials were inoculated at flowering stage (R6) by spreading PB diseased leaves on the crop. In 1989, a spore suspension prepared from infected leaves was used. PB was recorded at initial flowering (R6), pod filling (R7) and pod ripening (R8) in inoculated trials and at R7 only, in non-inoculated trials on a scale of 1 to 9, where 1 was disease free and 9, total destruction.

Table 1. Summary of Trials and Number of Entries Screened for Phoma Blight Resistance from 1987 to 1989.

Season	Trials	Source of seeds	Total number of entries	% entries scoring 1-2 at R7
1987B	Bush Nursery	CIAT	62	32
	Bush Nursery	Kawanda		
	Climber Nursery	CIAT	13	85
1988A	Climber Nursery	Kawanda	14	14
	AFBYAN I	African NPs	25	0
1988B	IBYAN *P. coccineus* spp *polyanthus* (climbers)	CIAT	10	70
	VEF 86 and CIAT accessions (bush)	CIAT	648	40
1989A	Great Lakes Regional Trial (climbers)	Rwanda	16	37
	G.L.R. Trial (bush), VEF 87, selections from VEF 86 and accessions	Rwanda/CIAT	108	9
1989B	AFBYAN II/regional nurseries and trials	African NPs	147	1.3
	International Nurseries			
	Climbers	CIAT	12	25
	Bush	CIAT	12	0

Entries selected for further screening and for use in crosses had resistance/tolerance to other major diseases, especially halo blight (*Pseudomonas phaseolicola*) and anthracnose (*Colletotrichum lindemuthianum*), both of which can be serious in cool conditions.

The results of the screening trials are presented in Table 1. Resistance was not consistent across seasons among bush beans. Fairly stable resistance was recorded for G 4603 (Pintado) and AND 556. Catu, Carioca and EMP 117 were extremely susceptible and are now being used as spreaders in screening trials. IBYAN (*P. coccineus* subs. *polyanthus*) entries exhibited good levels of resistance, the best line being G 35182. The lines that have been identified for inclusion in the EARPBN are: G 35182, G 4603, AND 556, Nain de Kyondo, BAT 1416, BAT 1565 and Urubonobono.

Hybridization Programme and Inheritance Studies

Following the initial screening in 1987, four bush bean genotypes (G

4603, BAT 1416, PAI 119 and BAT 1569) and two climbers (G 10747 and VRA 81051) were selected for crossing. In 1989A, four crosses (Rusipi x BAT 1416, Namunye Red x BAT 1416, PAI 119 X BAT 1416 and PAI 119 X BAT 447) were accomplished and the F_1s were grown in 1989B.

Crosses for the inheritance study were made at Kawanda and Kachwekano in 1989B. Thirteen bush bean crosses were completed at Kawanda. Problems encountered in these crosses included BCMV and black root which led to the loss of some crosses and poor pod set, especially in the climbers. At Kachwekano, the season was exceedingly wet, humid and windy and few crosses succeeded. The successful crosses will be advanced and the crossing will be repeated in 1990A.

Phoma Blight in Bean in Pure Stand and in Association with Maize

The behaviour of PB in pure stand and in association with maize and fluctuations in disease levels from season to season were examined in two experiments: the first involved cropping patterns and maize densities; and the second compared a range of bean genotypes.

The Effects of Cropping Patterns and Maize Densities on PB

Randomized complete block trials with three replicates were conducted at Kachwekano in 1987B and both seasons of 1988. The plot size was 3.6 x 6 m. The treatments, in a 2 (or 3) x 2 x 3 factorial arrangement, included two (or three) genotypes; two cropping patterns (maize within or between bean rows) and maize at three densities (11,111, 16,666 and 33,333 plants/ha). Two extra treatments (pure stand bean and farmers' practice) were included. In farmers' practice, maize was planted at 120 x 100 cm between bean rows. The bean was spaced at 60 x 10 cm. PB was recorded on a scale of 1 to 9 at R6, R7 and R8.

In 1988A, disease pressure was very low and differences between treatments were not significant. In none of the trials were there significant differences in PB levels between genotypes or maize densities. PB scores were larger where maize was between bean rows than where maize was within bean rows, the differences being significant at R6 in 1987B and 1988B and at R7 in 1988B (Table 2). Maize within bean rows appeared stunted and less able to influence the micro-environment than maize between bean rows.

In 1987B, 24 bean genotypes were compared in a split plot design with three replicates, with cropping patterns (bean in pure stand or in double rows between maize rows spaced at 90 x 30 cm) as main plots and bean genotypes as sub-plots. The trial was repeated in 1988A and B but with 40 bean genotypes. In 1989, the same layout was introduced for a regional PB trial with 20 entries. The objectives of the regional trial were: to study the resistance to PB across the region of a range of selected genotypes; to exploit different sources of resistance to PB; and to confirm the behaviour of PB in pure stand versus intercrop.

In 1989B, to increase the precision of the comparison of PB in pure stand and in association with maize, a two factor randomized complete block experiment with 5 replicates was initiated. The two factors were genotypes (3) and cropping patterns (2). Plot size was 4.5 x 6 m. PB was assessed on a scale of 1 to 9 at R5, R6, R7 and R8. In 1989, percentage leaf infection and number of lesions were also recorded, on ten randomly selected plants in each plot.

Table 2. Phoma Blight Levels on Bean Genotypes in Pure Stands and Within and Between Maize Rows at Kachwekano in 1987 and 1988.

		Stages of growth		
Season	Cropping patterns	R6	R7	R8
1987B	Within rows	6.55	7.55	8.27
	Between rows	7.00	7.94	8.39
	S.E.±	0.16	0.12	0.16
	C.V.%	10.3	6.6	8.3
1988B	Within rows	1.88	3.65	4.16
	Between rows	2.41	4.03	4.17
	S.E.±	0.18	0.21	0.25
	C.V.%	45.4	28.6	32.1

PB in Bean Genotypes in Pure Stand and in Association with Maize

In 1989B, the percentage of infected leaflets and number of lesions were significantly more on beans in association with maize than in beans in pure stand, but as disease levels increased with stage of growth, differences disappeared (Table 3). In none of the trials were there significant differences in PB scores between beans in pure stand and in association with maize. As expected, there were consistent significant differences among genotypes in PB scores. PVA 563 (from CIAT), Urubonobono (Burundi) and Nain de Kyondo (Zaire), all AFBYAN entries, and Pintado from the CIAT 1987 international PB nursery exhibited the smallest PB scores.

Control of Phoma Blight

Three chemical and cultural measures to control PB were investigated on three genotypes in a 4 x 3, randomized complete block trial with three replicates and a plot size of 4.2 x 6 m, at Kachwekano in 1988B, 1989A and 1989B. The control treatments were: seed dressing with Benomyl; seed dressing with Benomyl plus foliar application of Mancozeb at intervals of ten days from three weeks after germination to physiological maturity; roguing infected seedlings from emergence to the second trifoliolate leaf stage (V4); and a control. Percentage leaf infection by PB, number of lesions and PB score were recorded at R6, R7 and R8.

Seed dressing with Benomyl combined with foliar application of Mancozeb significantly reduced the number of PB lesions at R6 in all trials and at R8

Table 3. Phoma Blight Development on Beans Grown in Pure Stand and in Association with Maize at Kachwekano in 1988B.

	Cropping system	Stages of growth			
		R5	R6	R7	R8
Percentages of infected leaflets	Pure	41.4	49.8	57.6	NR
	Associated	48.7	48.4	60.3	NR
	S.E.±	1.53	2.08	1.79	NR
	C.V.%	22.9	18.7	29.4	NR
Numbers of lesions per ten plants	Pure	40.1	134.4	170.5	NR
	Associated	58.5	129.8	154.3	NR
	S.E.±	4.11	8.08	4.71	NR
	CV %	19.2	32.8	30.4	NR
PB score (1 to 9)	Pure	3.13	4.53	5.80	6.46
	Associated	3.46	4.80	6.07	6.46
	S.E.±	0.15	0.15	0.11	0.26
	C.V.%	15.7	20.6	13.9	10.8

NR = not recorded

in 1988B (Table 4). Roguing tended to decrease the disease in both seasons of 1989 though not significantly. Percentage leaf infection by PB was also significantly reduced by the combined seed dressing/foliar application of Mancozeb. In 1989B, there were significant increases in disease with time (b = 0.88) and reduction in PB (13.5%) due to seed dressing/foliar application of Mancozeb. In 1989A, seed yields were increased significantly by seed dressing/foliar application of fungicides but yield differences were not significant in the other two seasons. Angular leaf spot was severe in 1989A and its control may have contributed to the significant increases in yield due to fungicide application. PB was very severe in 1989B and the 10 day spray interval may have been too long to control the disease.

Cleaning Seed by Growing in a Disease Free Environment

Since PB is seed borne, seed production in lower altitude, warmer environments could be a useful control measure.

Seed from a heavily infected crop (90-100% plant infection) was harvested from Kachwekano in 1989A and planted at Kawanda in 1989B. PB was recorded in 6 x 10 cm randomly chosen plots and percentage plant infection was computed.

Table 4. The Effects of Cultural and Chemical Control on Numbers of PB Lesions per Ten Bean Plants Transformed to Square Roots (actual values in parentheses) and Seed Yields, at Kachwekano in 1988 and 1989.

Season	Treatment	Stages of growth R6	Stages of growth R8	Seed yields (kg/ha)
1988B	Benlate + Mancozeb	1.39 (1.78)	1.47 (2.11)	1592
	Benlate	3.45 (12.89)	4.32 (18.71)	1436
	Roguing	3.62 (14.11)	4.58 (21.10)	1422
	Control	3.40 (12.78)	4.01 (16.11)	1460
	S.E.±	0.28	0.24	143.4
	C.V.%	28.4	19.6	29.1
1989A	Benlate + Mancozeb	2.73 (7.45)	2.91 (8.47)	1704
	Benlate	4.20 (20.17)	3.91 (15.29)	1094
	Roguing	4.07 (17.58)	3.39 (20.16)	1015
	Control	4.34 (21.67)	4.40 (19.36)	990
	S.E.±	0.39	0.49	117.9
	C.V.%	35.3	46.7	34.0
1989B	Benlate + Mancozeb	6.09 (38.58)	11.00 (124.00)	624
	Benlate	8.12 (70.08)	11.63 (137.00)	595
	Roguing	7.08 (52.50)	11.22 (128.67)	572
	Control	7.28 (55.92)	11.37 (131.25)	520
	S.E.±	0.36	0.36	38.2
	C.V.%	17.6	11.2	22.8

Percentages of 1.66-1.83 and 6.50-8.67 were recorded at flowering and at pod-ripening, respectively. This suggests that producing seeds in warmer, lowland areas could eliminate seed infection but further work is required on this aspect.

Conclusions and Future Plans

1. Resistant lines have been identified. The breeding programme will be intensified. *P. coccineus* subsp. *polyanthus* accessions will be introduced as donor parents. Gene pyramiding and mutation breeding will be utilized.

2. Entries have been identified for the EARPBN and others are being sought. The EARPBN will be evaluated across locations.

3. Pathology work will shift emphasis from studies of PB development in pure stand and in association to studies of the epidemiological factors

which cause PB levels to fluctuate so widely across seasons and possibly locations. The study of PB pathotypes in the region has been started and will be expanded. Infection rates and transmission require increased attention.

4. Resistance, disease forecasting and chemical control are important components of the integrated control package we are aiming at and hope to achieve if the study is funded for two and half more years.

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Bean Rust: Its Importance, Epidemiology and Control In The Eastern Africa Bean Production System

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Abstract

The importance, epidemiology and control of rust (Uromyces appendiculatus) of phaseolus bean were studied in greenhouse and field experiments in Ethiopia. Rust was found widely distributed in southern Ethiopia, especially on state farms and research centers. Its severity and prevalence under farmers' conditions were small. Damage by rust to common bean was studied in field experiments at Ambo and Awassa. Years, locations and cultivars affected the damage equation, but that rust reduces the yield of bean is established. Studies of the pathogenicity of three rust populations revealed the existence of a high degree of variability among and within regions. In varietal resistance studies, several genotypes were found to possess multiple resistance. These lines will be important for bean production mainly in southern Ethiopia where environments are most favourable for rust. An integrated control program must be established for the region.

Introduction

Common bean (*Phaseolus vulgaris* L.) suffers from a wide range of leaf, stem and root diseases, including common bacterial blight, rust, anthracnose, angular leaf spot, web blight and bean common mosaic virus. In Ethiopia, common bacterial blight, rust and anthracnose are most important and widely distributed while the rest, though important, are much more restricted in their distributions.

Among these numerous diseases of beans in Africa, rust caused by *Uromyces appendiculatus* (Pers.) Unger var. *appendiculatus*, merits close attention. A preliminary survey (Habtu, 1987a) conducted in Ethiopia indicated bean rust to be important in bean production but did not address the prevalence and intensity of bean rust under farmers' conditions and practices. Surveys need to be conducted at regular intervals to describe the geographic distribution of diseases (Zadoks, 1961; James, 1969; King, 1972), to monitor changes in their relative importance and elucidate their epidemiology.

Bean rust is a major cause of low average yields of common bean in Ethiopia, estimated to be about 600 kg/ha. Severe incidences of bean rust were reported in southern, south-western and mid altitude cooler regions (Habtu, 1987a). A severe out break of rust resulted in nearly total yield loss in highly susceptible cultivars at Awassa (Habtu, 1987b). In Tanzania (Howland and Macartney, 1966), highly susceptible varieties were found completely defoliated by mid-flower, resulting in severe reductions of grain yield. Early work in eastern Africa suggested that severe infection by rust could decrease bean yields by 10% (Padwick, 1956). In Kenya (Singh and Musiyimi, 1981), 37% yield loss was reported.

Most of these conclusions were based on either visual observation or preliminary field work and few data exist on the relationship between disease reaction and yield loss. It is thus important to develop functions to relate damage to temporal and spatial injury with respect to crop growth and development.

Host plant resistance is a long-practised method of rust control. Evaluation of local germplasm and introduced materials have been conducted and good sources of resistance have been identified. In Ethiopia, the cultivars, Mexican 142, Black Dessie and Brown Speckled, were recommended for their resistance to diseases. Now, however, the widely cultivated Mexican 142 appears susceptible to most foliar diseases, particularly bean rust. Cultivars with black seeds (Black Dessie and Negro Mecentral) continue to express excellent disease resistance but are not acceptable to farmers because of their seed color. Attempts to identify genotypes with stable resistance and acceptable seed type did not succeed, because those resistant at one location proved susceptible at others (Habtu, unpublished).

All genetic studies of rust resistance in beans to date indicate a monogenic mode of inheritance (Dias and da Costa, 1968; Grafton *et al.*, 1985). Such resistance does not provide permanent protection because the fungus is highly variable in pathogenicity. Variation in the fungus has been reported from the U.S.A. (Stavely, 1984), Australia (Ballantine, 1978), South America (Augustin *et al.*, 1972) and Tanzania (Mmbaga and Stavely, 1988). The pattern of races found in eastern Africa is not well understood.

Following review of the importance, distribution and control of rust, it was found necessary to study in detail its epidemiology and management. Thus a bean rust sub-project was proposed and approved by the Eastern Africa Regional Bean Project Steering Committee in 1987 with the following objectives:

1. understand bean rust status under Ethiopia conditions;
2. assess yield loss of dry bean due to bean rust;
3. investigate the physiological races of the bean rust fungus and study patterns of race distribution; and
4. strengthen the screening program in close collaboration with bean breeders and initiate a regional bean rust nursery.

Materials and Methods

The project's central activity was coordinated by the Institute of Agricultural Research experiment station at Melkassa. Laboratory and greenhouse activities were conducted at Melkassa and Ambo while field experiments were conducted at Ambo, Awassa, Areka, Debre Zeit and Arsi Negelle. Regional rust nursery sites include Kawanda (Uganda), Thika (Kenya), Zambia, Rwanda and Tanzania.

Bean Rust Survey

The rust survey was conducted in major bean production centers in the Rift Valley and southern Ethiopia. Sample fields were selected at intervals of 20 km along main roads. Sample points include farmers' fields and state farms. General impressions of slope, size and management were recorded before selecting sample fields and plants. Sample plants were selected from specified numbers of equally spaced paces along inverted "V" diagonals. The nearest plant to the right foot was chosen as the sample unit. Five to ten sample units were selected in each field sampled. Rust was assessed on a 1-9 scale (CIAT, 1987) at growth stages close to R8.

Assessment of Losses

Field experiments were conducted at Ambo and Awassa in split-plot designs with five replications. Bean cultivars (Negro Mecentral, 6R-395-08, Red Wolaita, Mexican 142 and Nazret Small-03) were in main plots and fungicide treatments (unsprayed and systemic fungicide, oxycarbinoxin - Plantavaz at 0.1% concentration - at 5, 10, 15 and 20 day intervals until maturity) in sub-plots.

In 1987 and 1988, all entries were included but, in 1989, Red Wolaita was omitted due to similarities in its rust reaction to Nazret Small-03. Negro Mecentral was also omitted because of its high resistance to rust.

In 1987 and 1988, susceptible varieties were severely damaged by anthracnose, complicating the interpretation of results. In 1989, seeds were treated with benomyl in an attempt to control anthracnose.

Diseases were monitored weekly, commencing with the first spray. Other data collected include pods/plant, seeds/pod, seed size and seed yield.

Race Identification

Samples of bean rust populations were collected from Ambo, Awassa, Arsi Negelle and Jima. The isolates were inoculated on 20 standard differentials (see Tables 9 and 10) supplied from CIAT, in both field and screenhouse.

Field tests

A randomized complete block design with three replications was used. The plots were single rows 3 m long and 60 cm apart and the susceptible cultivars, Nazret Small-03 and Mexican 142, were sown every five rows. Disease reactions were rated three times: at flowering, early podding and maturity.

Greenhouse tests

Five seeds each of the differentials were sown in 6 inch diameter pots and seedlings inoculated with the rust isolates 10-12 days after sowing using an atomized sprayer and concentrations of 2 x 10^4 spores/ml. Rust reactions were recorded daily from five days after inoculation to full pustule development. Rust reaction and intensity were rated at 12 days after inoculation according to Davison and Vaughan (1963).

Rust Screening Nursery

Field experiments were carried out at IAR Research Station, Awassa and Plant Protection Research Center, Ambo in 1987, 1988 and 1989. Rainfall, humidity and temperature data for the three year period are shown in Table 1. The nursery consisted of 99 entries in 1987 and 94 entries each in 1988 and 1989.

Table 1. Meteorological Data for some Test Sites 1987-89.

	Altitude (masl)	Rainfall (mm)	R.H. (%)	Temperature (°C)	
				Minimum	Maximum
Ambo	2100	NR	74	11.8	23.4
Awassa	1700	929	65	12.1	27.5
Melkassa	1500	687	53	14.7	29.1
Adami Tulu	1650	607	55	12.8	28.1
Jima	1750	1059	65	10.8	26.3
Bako	1550	1046	61	14.0	27.0

NR = not recorded

The plot size was 3 m x 60 cm. Mixed susceptible cultivars were sown 25 days prior to the test entries and resistant, intermediate and susceptible checks were sown every ten test entries. Though the nurseries were generally exposed only to natural rust inoculum, in some cases they were inoculated with local rust populations.

Rust reactions were evaluated 30-40 and 50-60 days after sowing on a 1-9 scale where: 1 = no visible rust symptoms; 3 = resistant, only few and generally small pustules on most plants, covering approximately 2% of the foliar area; 5 = intermediate, generally small or intermediate-sized pustules on all plants, covering approximately 5% of the foliar area; 7 = susceptible, mostly large pustules often surrounded by chlorotic halos, covering approximately 10% of the foliar area; and 9 = highly susceptible, presence of large and very large pustules, with chlorotic halos, covering more than 25% of the foliar tissue and causing premature defoliation.

Fertilizers were not applied. The nursery was weeded at least twice, at two weeks after emergence and just prior to flowering.

Results and Discussion

Bean Rust Survey

There were differences in prevalence and severity of rust among regions and farming practices (Table 2). In the hot and dry areas of the Rift Valley, where rainfall is normally erratic and temperatures rather warm, rust prevalence and severity are low and, in some cases, non-existent. In these regions, the most prevalent disease is common bacterial blight. In southern Ethiopia, where weather conditions are favourable, rust poses a serious threat to bean production. On research stations at Melkassa, Areka, Ambo, Debre Zeit and Awassa, rust was prevalent but of varying intensity. Rust reactions recorded in 1988 were greater than those in 1987 and 1989. Comparison of rust prevalence on farmers' fields, state farms and research stations indicated that severity and prevalence are much on research stations, intermediate on state farms and slight in farmers' fields.

Table 2. Disease Reactions of Beans on Research Stations, State Farms and Farmers' Fields in the Rift Valley and Southern Ethiopia.

		Disease reactions[a]				
Region	Cultivar	Rust	CBB[b]	ALS	ANTH	BCMV
Rift Valley	Mexican 142	1	2	0	1	1
Southern Ethiopia						
Research Centers	Several	3	3	2	2	2
State Farms	Mexican 142	2	1	0	2	1
Farmers fields	Mixed (Red Wolaita common)	1	2	0	1	1

[a] 0 = no reaction, 1 = slight, 2 = moderate, 3 = severe
[b] CBB = common bacterial blight; ALS = angular leaf spot; ANTH = anthracnose; BCMV = bean common mosaic virus

On research stations, intensive production of bean in concentrated areas has allowed gradual build-up of the pathogen, aggravated by the inclusion in trials of susceptible lines. State farms grow bean on very large areas. They also use a single cultivar - Mexican 142 - which is susceptible to rust. Disease increase is favoured by aggregation of host crops in space and time (Zadoks and Schein, 1979). Thus, bean rust has become endemic and severity has been increasing.

On farmers' fields, scattered occurrences of rust are observed, mainly along main roads, but severity is much less than on either research stations or state farms. There are many possible reasons. Farmers in Sidamo and Gamo Goffa grow many different cultivars, sometimes with seeds of mixed colour, size and shape. Farmers' bean fields are also rather scattered and in most cases associated with either maize, enset or coffee. The value of associated cropping in pest management is well-documented (van Rheenen *et al.*, 1981; Moreno, 1985).

Rust is more prevalent and severe in the south, probably due to optimum temperature and rainfall conditions, while differences within the region are mostly due to cultural practices. Maximum rust severities are found associated with aggregation of farm practices, cultivation of susceptible cultivars concentrated in space and optimum temperatures and rainfall.

During the survey only limited fields were selected and other important foliar diseases were not considered. A study in this area in the future must address other components of bean production systems such as severities of other diseases, for example CBB, which has been found more widespread than previously suspected. We must also establish the place of bean rust as a component in the multiple phytosystem that now prevails in bean production.

Yield Loss

The effects of bean rust on seed yields of haricot bean were studied at Ambo and Awassa. As Ambo and Awassa represent two different environments with different disease severities, the results are analyzed separately.

Ambo

No results are presented for 1987 as there was high incidence of anthracnose and most of the crop was completely destroyed. In 1988, natural infection of bean by rust in sprayed and unsprayed plots produced mean rust severities ranging between 3 and 5 (Table 3). Differences among treatments in rust reactions were not significant probably due to delays in spraying. Though there were differences among treatments in seed yields, there were no consistent trends.

In 1989, there was high incidence of rust and the three entries showed moderate to large rust reactions related to their levels of resistance. All spray schedules reduced disease reactions (Table 4), the least disease occurring with the most frequent sprays. The trend was consistent for all the three entries. Differences in seed yields were also observed.

Assigning an index of 100 to the dried seed yield at the lowest infection level, yield was reduced by 10-73% in Mexican 142, 6-67% in Nazreth Small-03 and 3-15% in 6R-395-08. Regressions of seed yield on rust reactions for the individual entries (Table 5) showed that yields of Mexican 142 were reduced by 203 g/plot (8.1%) for each unit increase in disease reaction. For Nazret Small-03, this was 127 g (6.5%), for Red Wolaita it was 132 g (5.4%), and for 6R-395-08, it was 82 g/plot (6.07%). For Negro Mecentral (resistant), there was no relationship between disease reaction and seed yield.

In 1989 (with Negro Mecentral and Red Wolaita omitted), the relationships between seed yields and rust reactions were highly significant accounting for 83-96% of the variation in seed yields. Per cent yield losses for every unit increase in disease reactions were 11.0% for Mexican 142, 8.7% for Nazret Small-03 and 3.9% for 6R-395-08. Rust caused very large reductions in yields of Mexican 142 in both seasons, followed by Nazreth Small-03 and 6R-395-08.

Table 3. Effect of Bean Rust on Disease Reactions and Seed Yields of Haricot Beans at Ambo in 1988.

Entries	Spray interval (days)	Disease severity (1-9)	Seed yield (g/plot)	Index	Per cent change in yield
Mexican 142	5	4	1800	100.0	0
	10	4	1830	101.7	+1.7
	15	5	1600	88.9	-11.1
	20	5	1380	76.7	-23.3
	Control	4	1450	80.6	-19.4
Nazreth Small-03	5	3	1315	100.0	0
	10	4	1630	123.9	+23.9
	15	5	1240	94.3	-5.7
	20	5	1660	126.0	+26.0
	Control	5	1110	84.4	-15.6
6R-395-08	5	4	1865	100.0	0
	10	4	2090	112.0	+12.0
	15	4	1920	103.0	+3.0
	20	5	1830	98.1	-1.9
	Control	5	1390	74.5	-25.5
Red Wolaita	5	3	1065	100.0	0
	10	4	1135	106.5	+6.5
	15	4	975	62.3	-37.7
	20	4	1070	91.5	-8.5
	Control	5	900	84.5	-15.5
Negro Mecentral	5	4	1100	100.0	0
	10	4	1315	120.0	+20.0
	15	4	1375	125.0	+25.0
	20	4	1130	103.0	+3.0
	Control	5	1250	114.0	+14.0

The r^2 values were also higher for Mexican 142 and Nazreth Small-03 and slightly less for 6R-395-08.

Awassa

In 1988, rust reactions were rated several times during the growing period but only disease reactions at maturity were used to relate to yields, as in Ambo. There were significant differences in rust reactions among entries and spraying with fungicide significantly reduced the rust reactions of Mexican 142, Nazret Small-03, 6R-395-08 and Red Wolaita (Table 6) but not of Negro Mecentral, which is resistant to rust. The most frequent sprays consistently produced the least disease reactions and the largest yields (index = 100%). Yield losses were small for Negro Mecentral (0.3-4.1%) and 6R-

Table 4. Effect of Bean Rust on Disease Reactions and Seed Yields of Haricot Beans at Ambo in 1989.

Entries	Spray interval (days)	Disease severity (1-9)	Seed yield (g/plot)	Index	Per cent change in yield
Mexican 142	5	1.8	1267	100.0	0
	10	3.2	1144	90.3	-9.7
	15	3.8	1108	87.5	-12.5
	20	4.2	1071	84.5	-15.5
	Control	6.8	341	26.9	-73.1
Nazret Small-03	5	1.6	1246	100.0	0
	10	3.2	1145	91.2	-8.8
	15	4.0	1016	81.5	-18.5
	20	4.6	1007	80.8	-19.2
	Control	8.0	417	33.5	-66.5
6R-395-08	5	1.4	1496	100.0	0
	10	2.8	1447	96.7	-3.3
	15	3.2	1359	90.8	-9.2
	20	3.8	1352	90.4	-9.6
	Control	5.2	1271	85.0	-15.0

Table 5. Coefficients of Regressions of Seed Yields on Rust Reactions and Percentage Yield Losses due to Rust of Entries in Trials at Ambo in 1988 and 1989.

	1988			1989		
Entries	Regression coefficient	r	% loss	Regression coefficient	r	% loss
Mexican 142	-203.3	0.30	8.1	-191.0	0.90	11.0
Nazret Small-03	-127.3	0.08	6.5	-133.5	0.96	9.7
6R-395-08	-131.7	0.65	5.4	-60.7	0.83	3.9
Red Wolaita	-82.5	0.40	6.1	NT	NT	NT
Negro Mecentral	+20.0	0.01	0	NT	NT	NT

395-08 (0-5.3%), large for Nazret Small-03 (19.2-27.6%) and intermediate for Mexican 142 (3.1-17.8%).

In 1989, the responses to application of fungicide were larger. Losses ranged between 4.1 and 23.3% in Mexican 142, 15.2 and 35.1% in Nazret Small-03 and 8.3 and 13.6% in 6R-395-08. (Table 7).

Regressions of seed yield on the rust reactions for the individual entries (Table 8) showed that yields of Mexican 142 were reduced by 4.4% for each unit increase in disease reaction. For Nazreth Small-03, this was 7.8%, for Red Wolaita it was 6.3% and for 6R-395-08, it was 3.9%. For Negro Mecentral (resistant), there was no relationship between disease reaction and seed yield. In 1989, the yields of Mexican 142 decreased by 3.2% for each unit increase in disease reaction, by 5.4% for Nazreth Small-03 and by 2.6% for 6R-395-08.

Table 6. Effect of Bean Rust on Disease Reactions and Seed Yieldsof Haricot Beans at Awassa in 1988.

Entries	Spray interval (days)	Disease severity (1-9)	Seed yield (g/plot)	Index	Per cent change in yield
Mexican 142	5	1.5	1339	100.0	0
	10	2.3	1297	96.9	-3.1
	15	3.8	1275	95.2	-4.8
	20	4.5	1129	84.3	-15.7
	Control	5.3	1101	82.2	-17.8
Nazret Small-03	5	1.7	1781	100.0	0
	10	2.8	1344	75.5	-24.5
	15	4.0	1320	74.1	-25.9
	20	4.0	1440	80.8	-19.2
	Control	5.5	1290	72.4	-27.6
6R-395-08	5	2.5	2894	100.0	0
	10	1.7	2914	100.7	+0.7
	15	2.5	2741	94.7	-5.3
	20	2.5	2902	100.3	+0.3
	Control	3.0	2743	94.7	-5.3
Red Wolaita	5	1.5	1518	100.0	0
	10	2.8	1389	91.5	-8.5
	15	2.7	1344	88.5	-11.5
	20	3.3	1239	81.6	-18.4
	Control	5.3	1117	73.6	-26.4
Negro Mecentral	5	1.5	2441	100.0	0
	10	1.5	2449	100.3	+0.3
	15	1.5	2341	95.9	-4.1
	20	1.7	2439	99.9	-0.1
	Control	2.5	2434	99.7	-0.3

In 1989, as other diseases were practically unimportant and rust severities correlated well with yield, rust is most likely responsible for observed crop losses relative to the yields of the most frequently sprayed plots. Crop loss varied among entries, years and locations, which can be

Table 7. Effect of Bean Rust on Disease Reactions and Seed Yields of Haricot Bean at Awassa in 1989.

Entries	Spray interval (days)	Disease severity (1-9)	Seed yield (g/plot)	Index	Per cent change in yield
Mexican 142	5	1.0	1955	100.0	0
	10	1.6	1875	95.9	-4.1
	15	2.4	1550	79.3	-20.7
	20	3.2	1565	80.0	-20.0
	Control	5.4	1500	76.7	-23.3
Nazret Small-03	5	2.0	1740	100.0	0
	10	2.0	1760	101.1	+1.1
	15	3.8	1475	84.8	-15.2
	20	3.4	1360	78.2	-21.8
	Control	7.8	1130	64.9	-35.1
6R-395-08	5	1.4	1990	100.0	0
	10	2.0	1825	91.7	-8.3
	15	2.0	1760	88.4	-11.6
	20	2.4	1825	91.7	-8.3
	Control	5.0	1720	86.4	-13.6

Table 8. Coefficients of Regressions of Seed Yields on Rust Reactions and Percentage Yield Losses due to Rust of Entries in Trials at Ambo in 1988 and 1989.

Entries	1988			1989		
	Regression coefficient	r	% loss	Regression coefficient	r	% loss
Mexican 142	-63.3	0.86	4.4	-101.2	0.68	5.2
Nazret Small-03	-127.0	0.71	6.8	-102.7	0.85	5.5
6R-395-08	-123.9	0.43	3.9	-51.7	0.50	2.6
Red Wolaita	-103.5	0.93	6.3	NT	NT	NT
Negro Mecentral	+22.4	0.00	0	NT	NT	NT

expected due to differences in disease resistance and variations in weather and their subsequent impact on rust initiation and development. Obviously, the relationships demonstrated are valid only within the limits of these experiments, but the more information of this sort that can be assembled, the greater will be the accuracy with which we can assess the yield losses due to rust and other diseases across environments.

Among other factors, final crop yields are influenced by the severities of the diseases that occur during crop growth, which are also related to the rates of disease progress. The apparent infection rate (van der Plank, 1963) plays an important role in establishing a prediction model for crop loss. The results presented here follow a critical point model. Critical point models estimate yield losses for any level of disease at a time when a specified level of disease is reached (James and Teng, 1979). They assume that years, environments and cultivars are typical in terms of duration and time of onset of disease and stability of infection rate. This may not be so under natural conditions, so future experiments should examine the role of initial infection and its subsequent development in yield loss.

Moreover, more than a single disease can be present at any one time (for example, angular leaf spot and common bacterial blight at Awassa and anthracnose and ascochyta blight at Ambo) and their contribution to yield loss cannot be neglected in establishing prediction models. It is thus essential to collect more precise data to establish multiple point models by continuing field experiments, repeated both in time and space.

Pathogenicity of Rust Isolates

Studies of the reactions of the 20 rust differentials to Ethiopian rust isolates began in 1988.

In greenhouse tests at Melkassa, three isolates collected from Ambo, Arsi Negelle and Awassa were readily distinguished on the 20 differentials. The rust isolate from Ambo produced large pustules (500-800 microns in diameter) on Kentucky Wonder 780, Mountaineer and Olathe; medium-sized pustules (300-500 microns) on Kentucky Wonder 765 and Redlands Pioneer; small pustules (less than 300 microns) on US No. 3, CWS 643, Pinto 600, Early Gellatin, Brown Beauty and Aurora; and induced no reactions on Mexico 235 and 51051 (Table 9).

In nine of 20 cases the Ambo and Arsi Negelle isolates induced similar responses. However, the isolate from Arsi Negelle induced large pustules on Mountaineer, medium-sized pustules on US No. 3, Pinto 600 and Brown Beauty and no reaction on Mexico 235, Mexico 309, NEP 2, 51051 and CNC. These results and reactions on Golden Gate Wax indicate differences in pathogenicity between the two isolates.

In most cases, reactions to the isolate from Awassa were similar to either one or both of the isolates from Ambo or Arsi Negelle. Reactions differed on Golden Gate Wax, Ecuador 299 and Mexican 235 - on Golden Gate Wax, pustule size was between 300-500 microns, on Ecuador 299 less than 300 microns and on Mexico 235 only necrotic spots were produced.

Considering all three isolates, similar reactions were produced on CSW 643, Kentucky Wonder 765, Early Gellatin, Mountaineer, A x S 37 and 51051. 51051 was immune to all three isolates: A x S 37 induced only a necrotic response: CSW 643 and Early Gellatin gave small pustules: Kentucky Wonder 765 produced medium-sized pustules: and Mountaineer, large pustules for all isolates. However, the three isolates appear distinct: they not only differ one from the other, but there are indications of mixtures of isolates in each collection.

Table 9. Reactions of 20 Differential Bean Cultivars to Three Ethiopian Rust Isolates.

Differentials	Isolates		
	Ambo	Arsi Negelle	Awassa
US No 3	3	4	3
CSW 643	3	3	3
Pinto 600	3	4	4
Kentucky Wonder 765	4	4	4
Kentucky Wonder 780	5	4	4
Kentucky Wonder 814	3	2	2
Golden Gate Wax	3	5	4
Early Gellatin	3	3	3
Mountaineer	5	5	5
Redlands Pioneer	4	3	3
Ecuador 299	2	2	3
Mexico 235	1	1	2
Mexico 309	2	1	1
Brown Beauty	3	4	3
Olathe	5	4	4
A x S 37	2	2	2
NEP 2	2	1	2
Aurora	3	2	2
51501	1	1	1
CNC	2	1	2

In the field studies: high incidences of rust occurred at Awassa and Ambo in 1988 and 1989; incidences were intermediate at Debre Zeit and slight at Melkassa in 1988; and rust was absent from Debre Zeit and Melkassa and only slight at Arsi Negelle in 1989. Table 10 summarizes the reactions of the 20 differentials to some Ethiopian rust populations at Ambo and Awassa in 1988 and 1989 and Debre Zeit and Melkassa in 1988 only.

The classification was based on a 1-9 scale, where 1-3 was considered resistant (R), 4-6 intermediate (I) and 7-9 susceptible (S). On this basis, at least ten different responses can be distinguished, indicating the occurrence of at least 8 different isolates. The most prominent interactions were recorded on the differentials, Golden Gate Wax, Olathe, Kentucky Wonder 780 and Pinto 600.

In the greenhouse and field studies, variability in rust reactions occurred among isolates, indicating the presence of more than one isolate of the pathogen. The frequent occurrence of several isolates in collections of *Uromyces appendiculatus* is common (Stavely, 1984), indicating the existence of a wide range of natural diversity. The isolates used here were not collected from individual plants, neither were they properly described during collection. For clear identification of physiologic races of bean rust, homogeneous isolates need to be used and the date, place and cultivar of their collection should be recorded. Moreover, local and improved cultivars must be

Table 10. Reactions of Differential Bean Cultivars to Ethiopian Rust Populations at Ambo, Awassa, Debre Zeit and Melkassa in 1988 and/or 1989.

	1988				1989	
Differentials	Ambo	Awassa	DZ	Melkassa	Ambo	Awassa
Golden Gate Wax	S	S	S	R	I	R
US No 3	S	I	I	I	S	S
CSW 643	S	I	R	R	S	S
Olathe	I	S	S	R	I	S
Brown Beauty	I	I	I	R	R	R
Redlands Pioneer	I	I	R	R	I	R
Early Gellatin	I	I	R	R	R	R
Kentucky Wonder 765	I	I	R	R	S	S
Mountaineer	I	R	R	R	I	R
Kentucky Wonder 780	R	S	I	R	R	S
Pinto 600	R	I	S	S	R	I
A x S 37	R	I	R	R	I	I
Kentucky Wonder 814	R	R	R	R	R	R
Ecuador 299	R	R	R	R	R	R
Mexico 235	R	R	R	R	R	R
Mexico 309	R	R	R	R	R	R
NEP 2	R	R	R	R	R	R
Aurora	R	R	R	R	R	R
51051	R	R	R	R	R	R
CNC	R	R	R	R	R	R

included among the differential set to detect new, local rust genotypes that may not be distinguished by standard differentials alone.

Varietal Resistance

The rust reactions of entries in the 1987, 1988 and 1989 rust nurseries are summarized in Tables 11 and 12. In 1987, rust and anthracnose were severe at Ambo and common bacterial blight at Melkassa. The scores for bean rust ranged from 1 to 9 with a mean score of 3.22. Entries Cuva-168-N, Negro Jalpantagua-72, BAT 76, BAT 336, BAT 1629, Compuesto Chimaltenango, EMP 110, XAN 97, XAN 158, ZAA 84005, Black Turtle Soup, B 191 and CATU were found highly resistant, with no evidence of rust. Overall, 12 entries were susceptible, 24 moderately resistant and 64 resistant. When anthracnose and common bacterial blight are considered A 409, BAT 73, EMP 87, PVAD 1022, XAN 135, XAN 41, BAT 24, BAT 1629, EMP 110, Redland Pioneer, XAN 77, XAN 135, ZAA 84057, Bonita 42 Negra and ICA Pijao showed good levels of resistance to all three diseases.

Table 11. Disease Reactions of Entries in Rust Nurseries at Ambo and Melkassa in 1987.

Entries	Rust (Ambo)	CBB (Melkassa)	Anth (Ambo)
Aguascalientes 13	9	5	7
ACV 84053	4	2	4
A 177	7	6	2
A 197	4	5	6
A 409	2	2	3
Bountiful 181	5	6	3
Brown Beauty	5	4	3
BAT 73	2	2	2
BAT 1210	2	3	7
BAT 1426	5	4	2
BAT 1427	4	4	2
BAT 1428	4	4	2
BAN 24	2	2	5
BAT 1572	2	4	3
Canario 101	4	4	2
CC-GB-44 (G 3607)	2	4	2
CIAT 22 (G 5273)	4	5	2
Cuilapa 72-1 (G 4489)	2	4	2
Cuva 68-N	1	4	8
EMP 87	2	3	2
BAT 1287-1C-1C	3	4	3
G 13079	3	6	2
G 13145	3	5	2
G 13133	5	5	2
Jalisco 33	9	4	9
Kentucky Wonder 765	7	3	3
Mexico 6	7	4	3
Mexico 12	4	4	2
BAT 1257	2	4	2
Mexico 309 (G 5652)	2	4	6
Negro Jalpantagua-72	1	2	7
Pinto 650	8	2	9
PVAD 1022	2	2	3
N 128 (7641-501)	3	4	6
RAB 211	2	4	6
Turrialba 1 (G 4485)	2	4	4
Turrialba 4 (G 4465)	2	4	3
Veracruz 10	7	5	2
XAN 135	2	3	3
XAN 41	2	3	3
XAN 87	2	3	4
XAV 84078	4	5	2
ZAA 84006	3	4	3
ZAA 84044	4	2	2
ZAA 84065	4	4	2
51051 (G 3834)	2	4	2

Table 11 (continued).

Entries	Rust (Ambo)	CBB (Melkassa)	Anth (Ambo)
A 316	2	4	2
BAT 24	3	3	2
BAT 48	2	8	2
BAT 93	2	2	6
BAT 260	2	5	3
BAT 76	1	5	2
BAT 336	1	4	7
BAT 448	2	4	2
BAT 1629	1	2	2
BAT 308	2	4	5
California Small White	8	5	4
Guerrero 6	4	3	3
Guanajuato 10-A-5	2	5	3
Cocacho	4	4	3
Compuesto Chimaltenango	1	3	6
Epicure	2	4	4
Ecuador 299 (G 5653)	2	4	2
EMP 87	2	5	2
EMP 110	1	3	2
G 1099	2	4	3
Kentucky Wonder 780	7	4	8
Mulatinho A	3	4	2
Mexico 235	2	4	2
Negro 150	4	2	3
Ormiston	4	5	2
Redland Greenleaf C	5	5	2
Redland Greenleaf B	4	4	2
Redland Pioneer	3	2	2
RAB 128	4	5	8
RAD 34	5	4	7
RIZ 43	5	4	2
US No 3	6	4	6
VRA 81024	5	4	4
VRA 81028	2	4	2
VRA 81035	2	3	2
VRA 81066	2	4	2
XAN 97	1	4	6
XAN 77	2	2	2
XAN 158	1	3	3
ZAA 84005	1	3	4
ZAA 84057	2	3	2
ZAA 84093	2	4	1
A 176 (80 VEF 516)	2	4	2
CC-25-9	2	4	2
Black Turtle Soup	1	4	8
Bonita 42 Negra	2	2	2
B 191 (20290)	1	2	8
EMP 8-1C (78 VEF 211-1)	2	2	4

Table 11 (continued).

Entries	Rust (Ambo)	CBB (Melkassa)	Anth (Ambo)
CATU	1	4	5
ICA Pijao	2	2	3
Red Kloud	7	4	2
BAT 1102	7	4	4
Nazret Small-03	8	4	4
Mean	3.22	3.77	3.51
S.E.	0.202	0.110	0.200

Table 12. Disease Reactions of Entries in Rust Nurseries at Ambo in 1988 and 1989.

	1988			1989			
Entries	Rust	ANTH	ASC	ANTH	ASC	CBB	Rust
Olathe	9	7.5	6.5	2	3	4	7
BAT 448	2	3.0	4.0	2	2	4	2.5
P.I. 3388	6	2.5	7.0	2.5	4.5	4	4.5
997-CH-73	3	5.0	3.5	4	4.5	2.5	2.5
Veracruz 10	5	4.0	4.0	5.5	3.5	4.5	3.5
BAT 48	3	3.0	3.5	2.5	2	4	2.5
Pogoniom	8	2.0	6.0	2	4.5	4.5	3.5
Redland Autumn Crop	5	3.0	6.5	2.5	4	2	4.5
Brown Beauty	6	3.0	4.5	3	5.5	4.5	4
MCD 254	3	2.5	3.5	2	3	2	4
BAT 520	3	2.5	6.0	4.5	2.5	2	2.5
Redland Greenleaf (G 5746)	8	3.0	5.5	2.5	4.5	3	5
BAN 24	3	5.5	3.5	1.5	3	2	4
A 316	3	2.5	4.5	3	3	4	2.5
BAT 260	3	3.0	4.5	2	4	3	3
ZAA 84065	3	3.0	5.0	5.5	4	2	2.5
Mexico 309	3	9.0	5.0	6	2.5	2	2
XAN 147	3	3.0	6.5	2.5	2.5	3.5	2.
ZAA 84005	3	2.5	5.5	2	2.5	3	3.5
Compuesto Chimaltenango	3	3.5	3.5	3.5	4	2	3
BAT 1572	3	3.0	3.5	3.5	4	4	5.5
PAN 47	3	5.5	5.5	3	4	2	2.5
XAN 41	3	3.5	4.0	3.5	4	4	2
Guanajuato 10A-5	5	3.5	5.5	3	4	3.5	3
Mulatinho A	5	4.5	7.0	5.5	2	3.5	4.5
Bountiful 181	6	4.0	7.0	4.5	2	3.5	6
Jalisco 33	8	8.5	4.0	8	3	1	4
A 409	7	4.5	3.5	2.5	4	3	6.5

Table 12 (continued).

Entries	1988 Rust	1988 ANTH	1988 ASC	1989 ANTH	1989 ASC	1989 CBB	1989 Rust
Epicure	9	5.5	6.5	8	1.5	1.5	5
ZAA 84093	3	3.0	7.0	2.5	5	2	3.5
Turrialba 4	2	4.5	3.5	4	3	3	3.5
EMP 81	5	5.0	4.5	4	2	4.5	5
RAB 30	5	6.0	2.5	2.5	2.5	4	3.5
Canario 101	5	2.5	3.5	2	4.5	3.5	6
Guerrero 6	3	7.0	6.0	5.5	2.5	5	3.5
RIZ 43	2	2.0	4.5	3	2.5	3.5	3
Negro Jalpantagua 72	2	6.0	5.0	5	3.5	2	2
BAT 1210	3	7.5	4.5	4	2.5	1	3.5
Mexico 6	9	4.0	3.0	5	1	2	4.5
Mantequilla	8	3.5	5.0	1.5	6	3	7
NAG 37	5	6.0	8.0	4	5	3.5	2.5
BAT 76	3	3.0	4.5	2.5	3.5	3	3
Puerto Rico 5	2	8.0	6.5	5.5	3	2	3
ZAA 79	5	3.0	7.5	3	4.5	3	5
Negro 150	9	2.5	7.5	5	2	3.5	6
Kentucky Wonder 765	9	5.0	8.5	3	2	2.5	7.5
Compuesto Chimaltenango	3	2.0	5.5	3	3	3	3
California Small White	9	5.5	9.0	5	2	3	6.5
XAN 43	8	3.0	6.0	2	3.5	2	5
BAT 1427	3	2.0	8.5	2	4.5	2	4.5
XAN 97	2	6.5	6.0	7	3	2	3.5
Ormiston	2	5.0	6.5	2	6	2	4
ZAA 84044	5	2.0	8.5	2	6	5	4
Pompadour Cecha	6	2.0	6.5	1.5	5	3	4
EMP 110	2	4.0	6.5	4.5	3.5	4	3
Turrialba 4 (G 4466)	2	3.5	7.0	3	4	4	4.5
A 197	6	7.0	4.0	3.5	4	2.5	3
XAN 158	3	3.0	3.0	4.5	2	3	2.5
Cuilapa 72	2	5.5	6.5	3.5	4	4.5	2.5
BAT 93	2	6.0	6.0	3	3.5	3	1.5
ZAA 39	3	3.0	3.0	5	3	3.5	2.5
EMP 87	2	3.0	3.0	5	3	2.5	5.5
Mexico 235	2	3.5	4.5	3	3	2	2.5
RAD 34	3	5.5	4.0	4.5	3	3	2
XAN 87	3	8.0	3.0	5	2	2	2.5
Kentucky Wonder 814	3	7.5	6.5	5.5	3.5	4.5	4.5
Kentucky Wonder 780	8	9.0	5.0	8	2	2	2
XAN 135	2	3.0	4.0	6.5	3	2	2
Aguascalientes 13	9	3.5	3.0	4.5	3	2	8.5
ZAA 72	3	3.5	4.5	1.5	3.5	2.	3.5
XAN 77	2	4.5	6.5	4.5	3	2.5	2
Compuesto Negro Chimaltenango	2	3.5	4.0	5.5	2	2.5	1.5
CC-GB-44	6	2.0	2.5	3	3	2.5	4
BAT 1629	2	2.5	2.5	3	3	2.5	3.5
DOR 62	2	2.0	2.5	3	3	3	2

Table 12 (continued).

Entries	1988 Rust	1988 ANTH	1988 ASC	1989 ANTH	1989 ASC	1989 CBB	1989 Rust
AND 175	2	2.5	2.5	2	3	5.5	1.5
BAT 336	2	4.5	6.5	4.5	3.5	3	2
ACV 17	2	2.0	7.5	3	3	3.5	2.5
ZAA 65	5	2.0	6.5	2.	3.5	2	4
RAD 211	2	6.5	2.5	7	3.5	4	1.5
Cornell 149242	8	2.5	5.0	3	3.5	4	2.5
Veracruz-1-A-6	5	8.0	4.0	3.5	3.5	3.5	2
CAN 27	5	2.5	4.5	3	4.5	3.5	6
Guerrero 9	2	2.5	2.0	3	3	3.5	3.5
51051	3	3.0	4.0	6	4	3.5	2.5
Pinto 650	9	7.5	3.0	5.5	2.5	2	5
BAT 308	3	5.5	5.5	5.5	3.5	3	2.5
Mexico 12	9	4.5	3.5	4.5	3	2.5	5
Ecuador 299	3	3.0	3.5	2	3	1	2.5
Cuva 168-N	2	7.0	4.0	3.5	3	2	2.5
Redland Greenleaf (G 5653)	8	2.5	3.5	2.5	3	2	5
Golden Gate Wax	9	4.5	7.5	4	3	1.5	4.5
Redland Pioneer	5	3.0	6.0	1.5	3.5	5	4
US-3	9	7.5	7.5	3	4.5	2	2.0
Mean	4.40	4.25	5.03	3.74	3.33	2.95	3.62
S.E.	0.25	0.198	0.174				

In 1988, 94 entries were included in the nursery. There was a high incidence of rust at Ambo, accompanied by anthracnose and ascochyta blight. Scores for rust ranged between 2 and 9 with an overall mean of 4.4. The pathogen induced no reaction in 54 entries. Entries BAT 48, MCD 254, XAN 158, ZAA 49, EMP 87, BAT 1629, DOR 62, AND 175, Guerrero 9 and Ecuador 299 showed little or no reaction to all three diseases.

The same 94 entries were included in the nursery in 1989. All showed some reaction to rust. Scores ranged between 1.5 and 8.5 with a mean of 3.62. Entries with least reactions to the four diseases included Mexico 309, XAN 145, XAN 141, Negro Jalpantagua 72, BAT 93, RAD 34, Compuesto Negro Chimaltenango, AND 75 and RAD 211. BAT 448, BAT 93, Mexico 235, AND 75, ACV 17 and Ecuador 299 showed the least reactions to all four diseases.

Resistance in bean to rust and other diseases is not unique. Several sources of resistance to bean rust, anthracnose, common bacterial blight and bean common mosaic virus are reported (Coyne *et al.*, 1973). The results reported here confirm these findings and also indicate that there is a good possibility of identifying genotypes with resistance to one or more diseases in Ethiopia. Entries such as Redlands Pioneer, Ecuador 299 and BAT 448 were also found resistant to rust in Uganda and other diseases in Zambia. The regional rust nursery, which will begin in 1990, should provide information on the distribution of races across the region and help identify genotypes with stable resistance to rust.

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Analysis of Serotypes and Strains of Bean Common Mosaic Virus (BCMV) in Countries Within CIAT's Regional Programme on Beans in Eastern Africa

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Abstract

One hundred and seventy nine samples of bean plants showing virus or virus-like symptoms were collected from major bean producing areas of Uganda and Ethiopia. All were tested against antisera of two strains of BCMV (NL3 and NY15), ten other viruses and two monoclonal antibodies (BCMV-I-3 and BCMV-II-197) using a direct antibody sandwich type of ELISA. The tests indicated that of the samples that were infected with BCMV, in Uganda the vast majority were necrotic strains and in Ethiopia, non-necrotic. Incidences of other viruses were very low.

Introduction

The objectives of the sub-project are to:

1. survey and identify BCMV strains in eastern Africa;
2. evaluate/screen germplasm collections for resistance to BCMV strains prevailing in eastern Africa;
3. conduct comparative studies of pathotypes against promising materials; and
4. identify alternate hosts of BCMV and other viruses.

Although dry bean is an important source of edible proteins in most tropical countries, it is not immune to infection by seed transmitted viruses which pose serious risks in production and in improvement programs. Like other leguminous plants, bean is susceptible to natural infections by many viruses. Indeed there are reports in literature of approximately 30 different types of viruses affecting the grain legumes, bean, broadbean, cowpea, lentil, pea, peanut and soyabean. Of the 34 taxonomic groups of plant viruses approved by the International Committee on Taxonomy of Viruses, 12 contain at least one member which is seed transmitted in legumes. They are most numerous in the potyvirus group (nine), followed by the comoviruses (five), sobemoviruses (four), with one in each of the alfalfa mosaic, bromo-, carla-, furo-, ilar-, nepo-, pea enation-, tobamo- and tobraviruses.

The major seed-transmitted viruses in grain legumes and their natural hosts are: bean common mosaic virus (BCMV) of bean and mung bean; blackeye cowpea mosaic virus (BCMV) of cowpea; cowpea aphid-borne mosaic (CAMV), cowpea mild mottle (CMMV) and cucumber mosaic viruses (CMV) of bean, cowpea and mung bean; pea seed borne mosaic virus (PSbMV) of lentil and pea; pea early browning virus (PEBV) of pea; peanut mottle (PMV), peanut stripe (PSTV), peanut stunt (PSV) and southern bean mosaic viruses (ISBMV) of bean and cowpea; sunn-hemp mosaic virus (SHMV) of cowpea; and soyabean mosaic (SMV) and tobacco ring-spot viruses (TRSV) of soyabean.

In the majority of cases, transmission via seed is a consequence of infection of gametes leading to formation of infected embryos. Depending on the virus/host combination, seed transmission ranges from zero to 100%. Infection rates of 10-20% are common with a number of legumes. A notable exception to embryo infection appears to be sunn-hemp mosaic virus which is largely confined to the testa; there is no convincing evidence that the embryo is infected. In many cases of embryo infection, germination of the seed results in infected seedlings which, depending on the virus, may exhibit symptoms in youngest leaves. In the case of sunn-hemp mosaic virus, infection of the seedling probably arises from mechanical inoculation of the seedling by virus released from the seedcoat during germination.

Whatever the source of infection, the control of virus infection depends upon a clear understanding of epidemiological variables such as virus source, chance of transmission, susceptibility of the target crop and the influence of environment. Elimination of source, preventing transmission, which is usually very specific, or changing the target by using resistance or tolerance, or even a complete shift to a different crop, may prove useful.

Viable virus control and disease management starts with reliable detection and identification of strains of plant viruses. Two basic types of test are commonly used to detect viruses, especially in seeds. The first is biological, depending upon the appearance of symptoms in seedlings (growing-on test) or in indicator plants, inoculated with seed extract. The method has been used extensively and constitutes a useful first step in appraising a sample of seed for the presence of virus, but it is necessary to follow the test with definitive identification methods. It is the usual method of eradicating virus from germplasm collections. The infectivity assay method has been used in the detection of pea seedborne mosaic virus in commercial seed lots.

The second type of test utilizes various serological techniques, especially immunoduffusion, for example Enzyme-Linked Immuno-Sorbent Assay (ELISA) and Immuno-Sorbent Electron Microscopy (ISEM). Immunodiffusion methods are suitable for detection of isometric viruses but when used for detection of some filamentous viruses, modification of the gel medium or the antigen with detergents of alkaline PA is usually necessary to disassemble the nucleopeptide subunits so that they may diffuse more rapidly.

In this project, ELISA has been used extensively to detect BCMV strains in bean. This method is especially useful for group testing of seeds in which seed infection is low (1-5%). Such low levels are not amenable to detection by immunodiffusion methods because of their lower sensitivity. Development of "broad spectrum" serological probes, which can detect a wide range of viruses within a specific virus group, may find application in detecting seed-borne viruses and already a number of laboratories are investigating their application.

ISEM has been used to some extent, especially to circumvent problems with use of ELISA under conditions of high background absorbance. It may be a useful assay for relatively small numbers of samples but is unlikely to replace ELISA, which in most instances, is easier and cheaper to implement. Complementary DNA (cDNA) may find application for detecting viruses in bean seed extracts. It has been applied successfully in peanut seed infected with PMV and PSTV at lower levels than can be detected using ELISA. However, its use will probably be limited because most seed testing facilities do not have radio isotope facilities and the disposal of radioactive waste is a problem. Substitution of isotopically labelled cDNA by "cold" probes such as biotin would facilitate use of the technique. Criteria of increasing complexity can be used in virus identification and the choice of which to apply will depend on the facilities available. Immuno-sorbent assay has been the chief means of BCMV characterization in this sub-project.

Materials and Methods

Several bean growing areas of Uganda and Ethiopia have been surveyed for the purpose of collecting BCMV infected samples. In all cases, surveys were carefully planned to coincide with flowering to podding stages of bean crops, when BCMV symptoms are most conspicuous. Bean samples showing virus and virus-like symptoms were collected particularly from farmers' fields in various districts of Uganda and Ethiopia, with emphasis on diversity of environments.

Samples were analysed in a direct antibody sandwich (DAS) form of ELISA. Those samples which showed strong positive reactions and also others which gave negative reactions but came from plants which showed symptoms similar to BCMV in the fields at the time of sampling were run through infectivity tests. Sap transmission evaluations were conducted using cultivars Bountiful, Saxa, Black Turtle II and other test plants such as *Nicotiana benthamiana*, *N. clevelandii* and *Chenopodium quinoa*. Cultivar Monroe was especially used for local lesion tests.

In all cases, the samples were tested against antisera to the following common viruses: bean common mosaic potyvirus strain NL3, representing serotype A; bean common mosaic potyvirus strain NY15, representing serotype B; blackeye cowpea mosaic potyvirus; soyabean mosaic potyvirus; pea seedborne mosaic potyvirus; peanut mottle potyvirus; peanut stripe or azuki bean mosaic potyvirus; cowpea mild mottle carlavirus; clover yellow vein potyvirus; southern bean mosaic sobemovirus; bean mild mosaic virus; and squash leaf curl geminivirus. The monoclonal antibodies, BCMV-I-3 (specific for serotype A isolates of BCMV) and BCMV-II-197 (reactive with most BCMV isolates and with some other potyviruses) were used in the tests.

Differential varieties developed by Drijfhout in Wageningen (Table 1) were used in strain typing of both Ugandan and Ethiopian isolates. Because of the absence of greenhouses and screenhouses at Makerere, it has not yet been possible to initiate germplasm screening for BCMV resistance but it is hoped that it may be possible to conduct field inoculations in the forthcoming growing season (March-June, 1990) using CIAT materials.

Table 1. Differentiation and Grouping of Strains of BCMV.

	Non-necrotic strains					Necrotic strains				
Cultivars	I NL1	II NL7	IVa Fla	Va NY15	VII NL4	III NL8	IVb NL6	Vb NL2	VIa NL3	VIb NL5
Dubbele Witte	+	+	+	+	+	+	+	+	+	+
Stringless Green	+	+	+	+	+	+	+	+	+	+
Sutter Pink	+	+	+	+	+	+	+	+	+	+
Redland Greenleaf C	-	+	+	+to	+	-	+	+	+tc	+
Puregold Wax	-	+	+	+to	+	-	+	+	+to	+
Imuna	-	+to	+	+to	+	-	+	+	+to	+
Redland Greenleaf B	-	-	+	-	+	-	+	-	+	+
Great Northern 123	-	-	+	-	+	-	+	-	+to	+to
Sanilac	-	-	-	+	-	+	-	+	+	+
Michelite 62	-	-	-	+	-	+	-	+	+	+
Red Mexican 34	-	-	-	+	-	+	-	+	+	+
Pinto 114	-	-	-	+	-	-	-	+	+	+
Monroe	-	-	-	-	+	-	-	-	-	-
Great Northern 31	-	-	-	-	+	-	-	-	-	-
Red Mexican 35	-	-	-	-	+	-	-	-	-	-
Widusa	-	-	-	-	-	+n	-/+n	-	+n	+n
Black Turtle Soup	-	-	-	-	-	+n	-/+n	-	+n	+n
Jubila	-	-	-	-	-	-	+n	-/+n	+n	+n
Topcrop	-	-	-	-	-	-	-/+n	-/+n	+n	+n
Improved Tendergreen	-	-	-	-	-	-	-/+n	-/+n	+n	+n
Amanda	-	-	-	-	-	-	-	-	-	+n

+ = susceptible, systemic mosaic; +to = susceptible but tolerant, systemic mosaic symptoms questionable or very weak; - = resistant, no systemic symptoms; +n = susceptible, systemic necrosis, not dependent upon temperature; -/+n = susceptible or resistant, dependent on temperature, mostly only a few plants with systemic necrosis, variable and increasing with temperature

Results

In total, 179 samples from Uganda and Ethiopia were tested against the antisera. Where reactions occurred it was usually with BCMV antisera with occasional mild reactions to blackeye cowpea mosaic virus (Tables 2 and 3).

A large proportion of Ugandan isolates gave positive reactions with antibodies to BCMV-I-3 and in only rare cases were there reactions with an antiserum to BCMV-NY15. This pattern of reaction suggests that a vast majority of BCMV isolates from Uganda are serotype A isolates and are likely to be necrotic strains that cause systemic necrosis (black root) in bean cultivars possessing the dominant necrosis gene.

Incidences of other viruses such as cowpea mild mottle virus are very low among the samples tested. In one case, from a sample collected from a bean field 40 km North of Kampala, a gemini virus was detected using an antiserum to squash leaf curl virus. The validity of the reaction was confirmed using a test monoclonal antibody II-197.

There appeared to be differences in the distribution of pathotypes among locations. Serotype A was more common in mid-altitude (1,200 masl) warm areas (20-23°C) than in high altitude (1,400-1,800 masl) cool (12-16°C) mountainous regions. It can be inferred therefore, that cool areas tend to favour serotype B isolate distribution.

Table 2. Serological Reactions of BCMV Samples Collected in Uganda in 1988.

		Reactions[a]			
Sample no.	Symptoms	BCMV I-3	BCMV NY15	B1CMV	II-197
Bukalasa, Lwero District					
U01	crinkled	0	0	0	0
U02	BCMV	+++	+	+	+++
U03	BCMV	+++	0	0	+++
U04	BCMV	+++	0	0	+++
U05	BCMV	0	0	0	0
U06	BCMV	+++	0	0	++
U07	BCMV	++	0	0	+++
U08	BCMV	0	0	0	0
U09	BCMV	++	0	0	+++
U10	BCMV	+	0	0	+++
U11	BCMV	0	0	0	0
U12	BCMV	++	0	0	+
U13	BCMV	+++	0	0	++
U14	vein necrosis/BR?	0	0	0	0
U15	vein necrosis/BR?	0	0	0	0
U16	vein necrosis/BR?	0	0	0	0
U17	vein necrosis/BR?	0	0	0	0
U18	vein necrosis/BR?	0	0	0	0
U19	vein necrosis/BR?	0	0	0	0
U20	BCMV	0	0	0	0
U21	BCMV	+++	0	0	++
U22	BCMV	0	0	0	0
U23	BCMV	0	0	0	0
U24	BCMV	0	0	0	+++
Kiryandongo, Masindi District					
U25	BCMV?	0	0	0	0
U26	BCMV?	0	0	0	0
U27	BCMV?	0	0	0	0
U28	BCMV?	0	0	0	0
U29	BCMV?	0	0	0	0
U30	BCMV?	0	0	0	0

Table 2 (continued).

Sample no.	Symptoms	Reactions BCMV I-3	BCMV NY15	BlCMV	II-197
U31	BCMV?	+	0	0	+
U32	BCMV?	0	0	0	0
U33	BCMV?	0	0	0	0
3 km N of Mbale, Mbale District					
U34[b]	nutrient deficiency?	0	0	0	0
U35[b]	nutrient deficiency?	0	0	0	0
U36[b]	nutrient deficiency?	0	0	0	0
U37[b]	nutrient deficiency?	0	0	0	0
U38[b]	nutrient deficiency?	0	0	0	0
U39[b]	nutrient deficiency?	0	0	0	0
Tororo, Tororo District					
U40	BCMV?	++	0	0	++
U41	BCMV?	0	0	0	0
U42	BCMV?	0	0	0	0
U43	virus?	0	0	0	0
U44	virus?	0	0	0	0
U45	virus?	0	0	0	0
U46	virus?	0	0	0	0
U47	virus?	0	0	0	0
U48	suspicious, one plant	0	0	0	0
Nakabongo, Jinja District					
U49	Plot 142, BR?	+	0	0	+
U50	Plot 144, BR?	+	0	0	+
U51	Plot 222, BR?	0	0	0	0
U52	Plot 243, BR?	0	0	0	0
U53	Plot 253, BR?	+	0	0	++
U54	Plot 255, BR?	0	0	0	0
U55	Plot 314, BR?	0	0	0	0
U56	Plot 324, BR?	0	0	0	0
U57	Plot 345, BR?	0	0	0	0
U58	Plot 345, BR?	0	0	0	0
U59	Plot 353, BR?	++	0	0	++
U60	Plot 124, BR?	+	0	0	++
U61	Plot 132, BR?	+	0	0	+
U62	Plot 122, BR?	+	0	0	+++
Kachwekano, Kabale District					
U63	edge chlorotic	0	0	0	0
U64	cultivar Rushare suspicious	0	0	0	0

Table 2 (continued).

Sample no.	Symptoms	Reactions BCMV I-3	BCMV NY15	B1CMV	II-197
U65	crippled and variegated leaves	0	0	0	0
U66	plant completely yellow, BR?	0	0	0	0
U67	mosaic, not BCMV	0	0	0	0
Mparo, Kabale District					
U68	BCMV?	0	0	0	0
U69	chimera, other mosaic	0	0	0	0
U70	mild mosaic	0	0	+	+++
U71	yellow speckles	0	0	0	0
U72	crumpling with mild mosaic	0	0	0	+
U73	mottled leaves, BCMV?	0	0	0	0
U74	mottled leaves, BCMV?	0	0	0	0
U75	suspicious, clean field	0	0	0	0
Seta, Mpigi District					
U76	severe leaf roll	+++	0	0	+++
U77	typical BCMV symptom in field	0	0	0	0
U78	typical BCMV symptom in field	0	0	0	0
U79	typical BCMV symptom in field	0	0	0	0
U80	typical BCMV symptom in field	+	0	0	++
U81	typical BCMV symptom in field	+	0	0	++
Nakaseka, Lwero District					
U82	BCMV?	0	0	0	0
U83	BCMV?	+	0	0	++
U84	BCMV?	0	0	0	0
U85	BCMV?	0	0	0	0
U86	BCMV?	+	0	0	++
U87	plant yellowed, photo by Wortmann	0	0	++	++
U88	BCMV?	0	0	0	+
U89	BCMV?	0	0	0	0
U90	BCMV?	+++	0	0	+++
U91	BCMV?	0	0	0	0
U92	other virus?	0	0	0	0
U93	rugosed leaves	0	0	0	0
U94	typical BCMV	+++	0	0	+++

[a] +++ = strong, ++ = moderate, + = weak, 0 = no reaction;
[b] collected in off-season; BR = black root

Table 3. Serological Reactions of BCMV Samples Collected in Ethiopia in 1988.

Sample no.	Symptoms	Reactions[a] BCMV I-3	BCMV NY15	B1CMV	II-197
Melkassa					
700	BCMV	0	+	0	++
701	leaf rugosity	0	0	0	0
702	?	0	0	0	0
703	?	0	0	0	0
704	?	0	0	0	0
705	very mild BCMV	0	0	0	0
706	blister mosaic	0	++	0	+++
707	severe leaf distortion, not systemic	0	0	0	0
708	very mild leaf distortion, not systemic	0	0	0?	0
709	yellow speckle, systemic	0	0	0	0
710	yellow speckle, not systemic	0	0	0	0
711	BCMV?, atypical, on young leaf	0	0	0	0
712	seedborne BCMV?, severe leaf distortion	0	0	0	0
713	mosaic (genetic?)	0	0	0	0
714	golden yellow mosaic, 3 plants	0	0	0	0
715	?	0	0	0?	0
716	?	0	0	0	0
717	diffuse mottle	0	0	0	0
Alemtena					
718	deformation	0	0	0	0
719	mild vein banding	0	0	0	++
720	yellow mosaic, not systemic	0	0	0?	0
6 km S of Meki					
721	mild BCMV	0	0	0	0
722	mild BCMV	0	0	0	0
723	interveinal greening cotyledons, BCMV	0?	0	0	0
724	fine yellow speckles	0	0	0?	0
725	systemic leaf deformation	0	0	0?	0
726	mild BCMV-like, not systemic	0	0	0	0
Ziway Agricultural College					
727	crumpling	0	0	0	0

Table 3 (continued).

Sample no.	Symptoms	Reactions BCMV I-3	BCMV NY15	B1CMV	II-197
728	very severe leaf crumpling, LR	0	0	0	0
729	severe leaf crumpling and LR	0	0	0	0
730	single shrivelled leaf, not systemic	0	0	0	0
731	systemic leaf malformation	0	0	0	0
732	severe leaf curl	0	0	0	0
733	seedborne BCMV?, leaf deformation	0	0	0	0
734	severe leaf crumpling	0	0	0?	0
Awasa-Shashamene (large field)					
735	seedborne BCMV?	0	0	0	0
736	BCMV?	0	+++	0	+++
737	BCMV?	0	0	0	0
738	yellowing, nutrient deficiency?	0	0	0	0
Awasa					
739	mild mottle	+	0	+	++
740	mild mosaic (BCMV?)	0	+	+	+++
741	mild mosaic (BCMV?)	0	0	0	0
742	slightly necrotic veins	0	+	+	+++
743	some leaves with necrotic veins	0	+	0?	+++
744	spectacular necrosis few leaves	0	+	0?	+++
Hirna					
745	Mg deficiency?	0	0	0	0
746	Mg deficiency?	0	0	0	0
747	BCMV-like vein banding, not syst.	0	0	0?	0?
748	genetic mosaic, small plant	0	0	0	0
749	inconspicuous intervenal chlor.	0	0?	0	0
752	nutritional defect?	0	0	0	0
Alemaya (1960 masl)					
753	interveinal fine spots	0	0	0	0
754	slight leaf deformation, chlorotic spots	0	0	0	0
755	severe yellowing	0	0	0	0
756	mosaic, one leaf only	0	0	0	0
757/8	like 756 but apparently systemic	0	0	0	0
759	BCMV?	0	0	0	0
760	seedborne BCMV?	0	0	0	0
761	malformation (genetic?)	0	0	0	0

Table 3 (continued).

Sample no.	Symptoms	Reactions BCMV I-3	BCMV NY15	B1CMV	II-197
762	mosaic (genetic?)	0	0	0	0
763	BCMV	0	0	0	0
764	BCMV	0	+	0	0?
765	mild mosaic, not systemic	0	0	0	0
766	mosaic (genetic?), leaf malformation	0	0	0	0
767	bright yellow spotting	0	0	0	0
768/9	golden yellow mosaic, systemic	0	0	0	0
770	slight leaf deformation/ discoloration	0	0	0?	0?
771/2	severe leaf puckering	0	0?	0?	0?
773/4	fine chlorotic spots	0	0	0	0
Fenkele					
775	mosaic, not BCMV	0	0	0	0
776	maize				
777	maize				
778	maize				
779	chlorotic spots, necrotic centre	0	0	0	0
780	old plant	0	0	0	0?
781	sweet potato, diffuse chlorotic spots				
782	vein banding	0	0	0	0
783	slight leaf deformation	0	0	0	0
784	like 779	0	0	0	0
Miesso					
785	cowpea	0	0	0	0
786		0	0	0	0
Alemaya					
790[b]	chlorotic mosaic (070)	0	++	0?	0
791	leaf deformation, mosaic (071)	0	0	0	0
792	mild mosaic (072)	0	0	0	0
793	veinal mottle (073)	0	0	0	0
794	leaf deformation/crinkle (074)	0	0	0	0
795	chlorotic mottling (075)	0	0	0	0
Ziway					
796	mottle and vein banding (076)	0	+++	0	+

Table 3 (continued).

Sample no.	Symptoms	Reactions BCMV I-3	BCMV NY15	B1CMV	II-197
Awasa (Shallo)					
797	chlorotic mottling (077)b	0	0	0	0
798	chlorotic mosaic (078)	0	0	0	0
799	typical BCMV-like mosaic (079)	0	0	0	0
800	vein banding, leaf distortion (080)	0	+++	0	+++
801	leaf deformation, narrowing of young leaves, veinal chlorosis	0	0	0	0
Dire Dawa					
802	distinct chlorotic mottling (082)	0	0	0	0

[a] +++ = strong, ++ = moderate, + = weak, 0 = no reaction, ? = doubtful reaction;
[b] numbers in parentheses are Dr. Abdulrazak's sample numbers;
BR = black root

There was a marked contrast between the Ugandan and Ethiopian isolates. Whereas the Uganda isolates were predominantly A isolates of BCMV, the Ethiopian isolates were largely B isolates, reacting consistently positively with antisera to BCMV-NY15 and not with antiserum to BCMV-I-3 (Table 3). These differences between Ugandan and Ethiopian isolates have important implications in developing BCMV programmes for the two countries and exchange of breeding materials between them.

Future Plans

Future plans are to:

1. attend and participate in a workshop in Kampala on potyviruses;

2. prepare a report on progress made in the year 1989 and also draw up a budget for 1990;

3. survey viruses present in farmers' fields in lowland and highland areas of Kenya to compare Kenyan strains of BCMV with strains collected in Uganda and Ethiopia (the main purpose of this exercise is to draw up an inventory of BCMV strains occurring in Eastern Africa);

4. assist the CIAT breeder with field screening of segregating materials, particularly for resistance to black root;

5. carry out greenhouse screening against BCMV - type and NL-3 in Uganda;

6. request Michael Omunyin to conduct similar greenhouse screening of bean materials against the prevalent strains in Kenya;

7. conduct field screening for BCMV resistance of materials from Uganda national program; at two locations in Uganda;

8. prepare manuscript for Morogoro workshop;

9. attend Morogoro workshop and use opportunity to discuss work on BCMV in Tanzania with Professor Femi Lana of Sokoine University;

10. analyse results;

11. prepare progress report; and

12. prepare manuscript for publication in either Plant Disease, Annals of Applied Biology or Crop Protection Journal

Integrated Management of Beanfly (<u>Ophiomyia phaseoli</u>) On Haricot Bean

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Abstract

In sowing date x plant population trials grain yields and beanfly infestations were greater at Awassa than at Melkassa. Beanfly infestations and damage and grain yields increased with increasing plant populations at both locations. Beanfly infestation and damage increased at Melkassa and decreased at Awassa with delays in sowing. At Awassa, grain yields were less in the last sowing but sowing date did not affect grain yields at Melkassa. Among fifty entries screened for beanfly resistance at Awassa, DOR 62, A 114, Carioca, A 176, G 3844 and BAT 338-1C showed less beanfly infestation but there was no relationship between beanfly infestation and grain yields.

Introduction

Beanflies (*Ophiomyia* spp.) are the most important insect pests of beans in several countries of eastern Africa. In Ethiopia, beanfly (*Ophiomyia phaseoli*) can cause a total failure of haricot bean under extreme conditions. Infestation levels of up to 100% are common and yield losses range from 14 to 35%.

Insecticides, host plant resistance and improved cultural practices provide dependable opportunities for small farmers. Against this background, screening, sowing date and plant population trials were conducted at Melkassa and Awassa in 1989.

Sowing Date x Plant Population Trials

Trials were sown in split plot designs with four sowing dates (26 June and 6, 15 and 24 July at Melkassa; and 27 June and 7, 17 and 27 July at Awassa) as main plots and five plant populations (100, 200, 300, 400 and 500 thousand plants/ha) as sub-plots. The main plot size was 20 m^2. Data recorded included: per cent dead plants; per cent infestation with bean fly; numbers of plants with adventitious roots; numbers of bean flies; numbers of parasites; stand counts; and grain yields. Analysis of variance was computed for each parameter.

Grain yields and beanfly infestations were greater at Awassa than at Melkassa (Table 1). At both locations, beanfly infestation and damage decreased and grain yields increased with increasing plant population. Beanfly infestation and damage increased at Melkassa and decreased at Awassa as sowing was delayed. At Awassa, grain yields were reduced in the latest sowing but there were no significant effects of sowing date on grain yields at Melkassa. At Awassa, the numbers of parasites also declined with delays in sowing.

Table 1. Effect of Sowing Date and Plant Population on Beanfly Infestation and Yield of Haricot Bean at Awassa and Melkassa in 1989.

Treatments	Melkassa			Awassa						
	% dead plants	% beanfly infest-ation	Grain yield (kg/ha)	First stand count	% beanfly infest-ation	% advent-itious rooting	No. of beanfly per 20 plants	No. of parasites per 20 plants	No. of plants harv-ested	Grain yield (kg/ha)
Sowing dates										
26/27 June	13.03a	21.33a	1068a	449.5b	83.00a	6.67c	0.00c	45.93a	353.4b	3324a
6/7 July	9.51a	29.67ab	1256a	553.2a	98.00b	11.67c	5.93bc	22.33b	436.0a	3418a
15/17 July	7.32a	43.33bc	1170a	526.2a	77.33a	30.00b	4.27ab	12.13bc	401.1a	3369a
24/27 July	13.90a	52.67c	925a	549.8a	73.33a	51.67a	3.20a	5.73c	426.0a	2891b
Mean	10.74	36.75	1105	519.7	82.92	25.00	5.35	21.53	404.6	3251
S.E.	1.94	2.62	115.2	10.01	3.68	2.20	0.60	3.31	12.25	122.6
C.V. (%)	6.88	27.6	40.4	7.5	17.2	34.2	43.6	59.6	12.3	14.6
Plant densities (000s plants/ha)										
100	13.27b	47.08b	768c	165.3e	89.58b	24.68a	7.67c	34.74a	120.2e	2531c
200	14.37b	37.50ab	989b	326.7d	79.17a	22.08a	7.03c	26.42b	254.6d	3281b
300	9.83a	36.25ab	1131ab	534.1c	84.58ab	29.58a	5.50bc	20.17bc	422.0c	3560a
400	8.18a	31.25a	1296a	732.7b	82.08a	25.42a	3.67ab	14.17cd	577.3b	3487ab
500	9.08a	31.67a	1339a	839.8a	79.17a	23.33a	2.92a	12.17d	649.1a	3394ab
Mean	10.94	36.75	1105	519.7	82.92	25.00	5.35	21.53	404.6	3251
S.E.	1.09	2.40	64.8	8.10	1.96	2.07	0.78	2.60	11.10	83.5
C.V. (%)	34.5	22.0	20.3	5.4	8.2	37.0	50.2	41.8	9.5	8.9

Means within a column followed by the same letter are not significantly different from each other at P = 0.05 according to Duncan's Multiple Range Test

Varietal Resistance

Fifty entries were screened for their resistance to beanfly at Melkassa and Awassa. At Awassa (Table 2), DOR 62, A 114, Carioca, A 176, G 3844 and BAT 338-1C had slightly lower infestation by beanflies, but only G 3844 exhibited no beanflies in a five plant sample. There was no relationship between grain yields and numbers of beanflies and parasites.

Table 2. Screening of haricot bean lines for resistance to beanfly at Awassa in 1989.

Entries	No. of plants	% plants infested beanfly	% plants advent-itious roots	No. of beanfly/ 5 plants	No. of parasites per 5 plants	No. of plants harvested	Grain yield (kg/ha)
G 5253	28.0	100	1.5	1.5	10.0	21.5	2098
G 2005	27.5	100	1.0	1.5	14.5	19.5	4665
G 5773	28.0	100	0.5	5.5	24.0	19.5	3622
G 2472	30.0	100	2.0	3.5	18.5	25.0	4367
G 3944	22.0	80	1.0	0	13.0	21.0	3184
G 158	28.5	90	0.5	1.5	12.0	21.0	1709
Mexican 142	30.5	90	2.0	0	8.5	20.0	2755
Red Wolaita	29.5	100	1.5	1.5	15.5	22.5	3483
A 410	29.5	90	1.0	1.5	17.0	24.0	2787
BAT 338-1C	25.0	80	1.0	1.5	18.0	16.0	3614

Table 2 (continued).

Entries	No. of plants	% plants infested beanfly	% plants advent-itious roots	No. of beanfly/ 5 plants	No. of parasites per 5 plants	No. of plants harvested	Grain yield (kg/ha)
Ex Rico 23	30.0	100	0.5	0	13.0	23.5	3920
Diacol Calima	30.5	100	1.0	1.0	21.5	25.5	3730
Carioca	26.5	70	0	3.5	7.0	21.5	4744
CCD 3579	27.0	90	0	0.5	16.5	22.0	3097
ICA 15551	29.0	100	0.5	1.0	22.5	25.5	3557
AND 327	29.5	100	1.0	1.5	13.0	21.5	3177
BAT 1629	27.5	100	2.0	1.5	19.0	20.5	3082
XAN 158	28.0	100	0.5	4.5	18.5	21.5	3618
AND 388	29.0	100	1.0	0.5	23.5	19.0	3917
Acc. No 325726	31.0	100	0.5	1.0	19.0	21.5	2459
AFR 191	28.5	100	1.0	3.0	11.0	24.0	3400
RIZ 22	27.0	100	0	1.0	24.5	18.5	3632
HAL 3	29.0	90	1.0	1.5	11.5	20.5	3999
G 841	28.0	90	0.5	1.5	22.5	21.5	3744
A 114	28.5	80	0.5	2.0	18.0	20.5	4769
AND 326	27.5	90	0.5	0.5	14.0	23.5	3184
AND 305	30.5	100	0.5	2.5	9.5	21.0	2935
AND 336	31.5	100	2.0	0.5	5.5	22.0	3587
Guerrero 6	28.0	100	1.5	2.5	8.5	21.5	4215
EMP 87	29.5	90	1.0	0.5	12.5	20.5	4513
DOR 32	28.5	60	0.5	3.0	15.0	22.0	4525
Ikinimba	29.5	100	1.0	3.0	22.5	22.5	3910
A 265	26.5	100	1.0	0.5	6.0	19.0	3727
A 445	28.5	100	0.5	1.0	22.0	24.5	3930
A 422	28.5	90	0.5	1.5	9.0	23.5	3954
BAT 85	27.0	100	0.5	1.0	7.5	21.0	3715
A 62	30.5	100	2.0	1.0	15.0	22.5	1683
A 176	29.5	80	0.5	0.5	9.0	20.0	3184
BAT 1281	22.5	100	0	1.0	15.0	16.0	2502
PAN 135	28.5	100	0.5	1.5	13.5	23.5	3985
BAT 1198	27.5	100	0	0	12.0	20.5	3717
A 262	29.0	90	0.5	2.5	9.5	21.0	2935
A 483	32.0	100	1.0	2.0	32.5	24.0	3767
Negro Mecentral	26.5	100	1.5	2.0	18.0	21.5	2494
G 2816	27.0	90	1.0	4.0	21.5	19.0	3039
GLPX 92	27.5	100	0.5	0.5	33.5	21.5	3799
AND 371	31.5	90	1.0	2.0	23.0	24.0	3065
PAN 112	31.5	90	1.5	0.5	11.5	26.0	4032
AND 280	30.0	90	0	1.5	17.5	25.0	3507
PAN 134	29.0	90	0.5	1.5	20.5	22.5	3849
Mean	28.5	94	0.8	1.6	15.9	21.7	3495
S.E.	1.62	6.4	0.53	1.03	5.21	1.72	401
C.V. (%)	8.0	9.6	89.9	92.6	46.3	11.2	16.2

Modified Work Plan for 1990

Following is the research proposal for 1990-91.

Beanfly Resistance Reconfirmation Nursery

Objective

To reconfirm the resistance of cultivars reported to be resistant to beanfly in Ethiopia and other environments.

Procedures

Design	Split plot, 3 replications
Main plots	1) Endosulfan treated seeds 2) Untreated seeds
Sub plots	11 bean cultivars (including local check)

Entry number	Entry name
1	EMP 81
2	G 2472
3	G 3696
4	G 5353
5	G 5773
6	Ikinimba
7	BAT 1373
8	A 74
9	ZPv 292
10	A 55
11	Local check

Plot size	8 rows X 2 m	
Crop management	Local practice	
Locations	Awassa and Melkassa	
Data to be collected		
	One week after emergence	Stand count
	Four weeks after emergence	Seedling mortality rate (no./row), damping off, dead plants; plant vigor on 1-9 scale (1 = vigorous, 9 = very poor); uproot 10 adjacent plants and rate them individually for adventitious roots and stem cracking; dissect stems and count larvae and pupae per plant
	Maturity	yield data on central rows

Segregating Populations and Beanfly

Promising entries with good bean fly resistance have been crossed with lines with good seed qualities. These crosses are to be tested for bean fly resistance.

Objectives

To select within and among segregating bean populations, plants that are superior for yield and bean fly resistance.

Procedures

Populations - 58 F_2s.

For bush types use 10-20 cm between seeds and 50-60 cm between rows.

For semi-climbers use support systems (stakes, maize) 60-100 cm apart for individual selection of plants at harvest.

Cultural practices - grow where uniform bean fly pressure
Locations - Melkassa and Awassa

Data to be collected

- growth habit
- diseases on a scale of 1 to 9, where 1 = no damage and 9 = severe damage
- vegetative vigor at flowering (1 to 9 scale, 1 = very vigorous, 9 dead or dying)
- reproductive efficiency (visual estimation of pod load at harvest, 1-9 scale, 1 = excellent, 9 = very poor).
- Number of individual plants selected from the population when a pedigree strategy is used. If the seed is harvested in bulk or single pod descent, this should be indicated.

Cooperators - Awassa (IAR)
Teshome Girma, Melkassa (IAR)

Grain Legume Storage Pest Control in Somalia

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Abstract

A survey in Lower and Middle Shabelle Provinces of Somalia in February 1990 indicated that cowpea is the most important grain legume with mungbean and Phaseolus spp. accorded less priority. The three species are grown in both seasons, usually in association with maize or sorghum. Insects are major constraints in field and store. Lack of appropriate husbandry practices, birds, rodents and drought are also limiting. Drums, sacks underground pits and other containers (for example ugulow) are used to store legume seeds. Drums are the most efficient and sacks the least. Of seven cowpea lines from IITA tested in the laboratory for their resistance to Caliosobruchus maculatus, three (IT81D-1007, IT84S-2246-4 and IT85F-2205) showed less infestation and damage and will undergo further testing. Treatment of cowpea seeds with groundnut and sesame oils proved to give good control of C. maculatus in a laboratory test and will be examined further. Seed treatment with neem seed oil and banana ash were less effective.

Introduction

Several species of grain legumes are cultivated extensively by smallholders in Somalia, including cowpea (*Vigna unguiculata* L.), mungbean (*V. radiata*) and lima bean (*Phaseolus lunatus*) (*buluko*). Ninety percent of farmers intercrop grain legumes with cereals mainly maize. The grain legumes are usually broadcast among the main crops and continue growing and producing after the cereal crop is harvested. This system results in very poor grain legume yields. The use of grain legumes in pure stand is limited by heavy insect attack at different stages of crop growth which reduces farmers' interest in grain legume production. Poor cultural and storage practices also contribute to the poor yield.

Stored grain pests of grain legumes are serious in the tropics, where temperatures and humidities are suitable for insect growth and reproduction. The most destructive pests are the weevils, *Callosobruchus maculatus* on cowpea and *Acanthoscelides obtectus and Zabrotes* spp. on common bean.

Techniques that keep beans in storage free of insect pests would clearly provide economic benefits to bean growers and bean consumers as well as providing markets with better quality produce.

The objectives of the present study were threefold: to survey storage practices; to screen introduced cowpea lines for resistance to storage pests; and to assess the value of seed treatment with various vegetable oils and with banana ash for control of storage pests.

Materials and Methods

Survey

A questionnaire was prepared to survey areas in middle Juba in 1988 and Lower and Middle Shabelle Provinces in 1990. For the latter, 21 farmers growing grain legumes were selected in 15 villages. Cropping systems, storage facilities, control measures against pests and methods of utilization were noted and losses due to major constraints in field and store and grain yields were estimated.

Screening for Resistance

The resistances of eight cowpea genotypes were assessed. They included seven lines considered to have resistance to bruchids, introduced from the International Institute for Tropical Agriculture at Ibadan in Nigeria, and a local check.

Seed Treatment

Newly harvested seeds of a local cowpea cultivar were mixed with groundnut, sesame and neem seed oils at the rate of 5 ml of oil per kg of seed. For the banana ash treatment, the ash was sieved through a 1 mm mesh to eliminate large particles and mixed thoroughly with the cowpea seeds at the rate of 200 g ash per kg of seed.

Infestation

Adult bruchids were introduced into glass bottles containing about 0.5 kg freshly harvested seeds of a local cowpea cultivar, left four days for egg deposition and then removed.

One hundred grammes of seeds of each treatment (for both screening and seed treatment trials) were placed in each of four glass bottles, infested with 10 newly emerged adults and covered with perforated lids - on 28 September 1989 for the screening trial and 29 September for the seed treatment trial.

Observations and Analysis

The numbers of eggs and holes per 100 seeds and of adults in each bottle were counted three times at various intervals (see Tables 6 and 7) after infestation. The data were transformed to log (x+1) and means separation was by Duncan's Multiple Range Test.

Results and Discussion

Survey

Average farm size is 11 ha and most of the area is under crops in both *gu'* and *der* seasons (Table 1). More than half the farmers cultivated less than

5 ha of land.

Table 1. Farm Sizes (ha) and Land Areas cultivated in *Gu'* and *Der* Seasons in Middle and Lower Shabelle in 1990.

Farm size	No. of farmers	Average farm size	Season of crop *gu'*	*der*
Less than 2.5	5	1.2	1.2	1.2
2.6-5.0	7	4.0	3.3	3.1
More than 5.1	9	21.8	17.8	18.5
Total/mean	21	11.0	9.0	9.3

Most farmers cultivated grain legumes (especially cowpea) in association with maize in both *der* and *gu'* seasons (Table 2). The grain legumes are broadcast among the growing maize. Only a few farmers grow common bean, which is broadcast around the edges of fields and accorded little priority. Sesame (in the dry season) and maize are frequently grown in pure stand, mainly by larger farmers.

Table 2. Areas (ha) in Pure Stand and Associated Cropping for Different Farm Sizes in Middle and Lower Shabelle in 1990.

Farm size (ha)	Total	Pure stand *gu'*	Pure stand *der*	Associated *gu'*	Associated *der*
Less than 2.5	1.2	0.05	0.10	0.70	0.65
2.6 to 5	4.0	0.96	0.07	2.75	1.64
More than 5.1	21.8	4.39	11.50	9.40	6.40

In both regions surveyed, the four major crops are maize, sesame, cowpea and mungbean. Except for sesame, yields are greater in the *gu'* season (Table 3). Most farmers grow sesame for oil, which has a satisfactory price in the market. Cowpea is always in association with maize and its yield is generally poor due to sparse populations and heavy insect attack. Mungbean yields less than cowpea and its cultivation has been largely abandoned due to shattering.

All farmers suffered losses due to insects (Table 4). In the field, the major insects observed in both provinces were *Maruca testulalis*, aphids, sucking bugs and beanflies. In store, bruchids were destructive in cowpea and mungbean. Other problems encountered by farmers included diseases (3.3%), birds (48.6%) and rodents and pigs (12%).

Table 3. Grain Yields (kg/ha) in Middle and Lower Shabelle in 1990.

	cowpea		mungbean		maize		sesame	
Farm size (ha)	*gu'*	*der*	*gu'*	*der*	*gu'*	*der*	*gu'*	*der*
Less than 2.5	280	320	220	180	1700	100	20	240
2.6 to 5	350	80	90	NR	2500	580	NR	560
More than 5.1	311	70	27	72	1355	120	NR	544
Mean	314	157	112	84	1852	267	7	448

NR = not recorded

Table 4. Percentage of Farmers having Problems in Growing Grain Legume Crops in Middle and Lower Shabelle in 1990.

Farm size (ha)	Number of farmers	Insects	Diseases	Birds	Rodents and pigs
Less than 2.5	5	100	0	60	0
2.6 to 5	7	100	0	42	14.3
More than 5.1	9	100	11	44	22
All farms	21	100	3.3	48.6	12

For storing grain, about 82 per cent of farmers surveyed used drums, in which grains can be kept for a period of one to two years with little or no infestation (Table 5). Farmers stated that this kind of storage is effective only if drums are maintained full and air tight. About 10 per cent of farmers used sacks as a means of storage, mostly as unthreshed grains. This method was reported to be ineffective and could not be relied on for more than one week because of rapid infestation by bruchids. About 5 per cent of farmers used underground pits for unthreshed grains. The method was reported effective for control of bruchids for a period of one year but seeds become hard and take a longer time to cook and lose germination ability. Other methods used include the *ugulow* (a fabricated basket) usually hung over the fireplace to be disinfected, but this method is ineffective.

Seeds of the local check and the IITA line IT86D-534 had significantly more eggs and holes per 100 seeds and more adults than the other treatments at most times of sampling (Table 6). Seeds of IT81D-1007, IT84S-2246-4 and IT85F-2205 had significantly less infestation and damage than other entries at most times of sampling and IT84S-275-9, IT86D-472 and IT81D-1137 were intermediate.

Numbers of adults were much fewer than numbers of eggs, indicating that many of the eggs laid must have failed to hatch. Also there was considerable mortality of young adults in the first time of sampling, especially in entries

Table 5. Methods of Storage, Average Period of Conservation and Level of Losses of Grain Legumes in Middle and Lower Shabelle in 1990.

Storage method	Per cent of farmers	Duration (months)	Level of loss
Underground pit	5.5	14	light
Drum	81.9	12-24	light
Sack	10.8	1	heavy
Other	1.8	6	heavy

Table 6. Numbers of Eggs and Holes per 100 Seeds and Numbers of Bruchid Adults on Three Occasions in Seeds of Cowpea Lines infested with *C. maculatus*.

Entries	Nos. of eggs/ 100 seeds			Numbers of adults			Nos. of holes/100 seeds		
	25[a]	32	39	48	53	58	47	59	66
IT86D-534	119a	187a	518a	2.00	27.75	38.00a	40.00b	89.50a	119.75a
IT84S-275-9	38c	88ab	136bc	22.50	6.75	3.00c	5.75c	29.00b	18.75c
IT81D-1007	44c	37c	99bc	1.75	11.00	2.00c	6.75c	14.50cd	17.00c
IT86D-472	36c	54b	124bc	1.50	5.25	15.50b	8.50c	26.50bc	25.50c
IT84S-2246-4	34c	35c	93c	1.75	7.50	0.75d	8.00c	10.25d	13.00d
Local check	52b	147a	620a	22.50	14.75	20.50ab	62.50a	37.00ab	59.00b
IT85F-2205	20d	54b	88c	1.75	15.50	3.00c	6.25c	6.50e	12.00d
IT81D-1137	55b	72b	205b	2.50	7.75	5.75b	9.50c	19.25c	39.50b
CV(%)	9.7	9.3	13.0	??.?	??.?	30	30	29	23

[a] number of days after infestation
Means in the same column followed by the same letter do not differ significantly from eachother at P = 0.05

IT81D-1007, IT84S-2246-4 and IT85F-2205. Although there appeared to be clear differences among entries in infestation and damage, there was no attempt to study the mechanisms involved.

One or more of the three entries with the least bruchid infestation and damage may be released to farmers for practical field assessment and promotion if their yields and agronomic and cooking qualities are satisfactory. Even relatively poor yields may be acceptable if the lines survive well in farmers' stores.

Further resistant lines will be sought from IITA if progress is made with their other agronomic properties, including resistance to field pests.

Seed Treatment

At the first two times of sampling there were significantly fewer eggs on seeds treated with banana ash than on seeds treated with vegetable oils or untreated (Table 7). At the third time of sampling, seeds treated with banana ash or untreated had significantly more eggs than seeds treated with vegetable oils among which groundnut and sesame oils appeared to give best control. Banana ash may have hampered oviposition on seeds initially but subsequently settled, exposing seeds to oviposition.

As in the screening trial, adults were much fewer than eggs laid. Their numbers were significantly fewer in seeds treated with banana ash than in seeds treated with vegetable oils or untreated at the first two times of sampling, except for the sesame oil treatment at the second sampling. By the third sampling, differences between treatments were not significant.

Seeds treated with vegetable oils had significantly fewer holes than seeds treated with banana ash or untreated.

Thus sesame and groundnut oils proved to be effective in controlling *C. maculatus*, reducing egg deposition and damage. Similar results have been obtained elsewhere in Africa. For instance Pere *et al.* (1985) reported that sunflower oil can effectively control bruchids, the rate of only 2 ml oil/kg seed giving virtually complete control. In our trials, oil applied at 5 ml/kg seed gave satisfactory control of bruchids. Although various neem products have been reported to control insect pests in a variety of conditions, the neem seed oil treatment in this trial was less effective than sesame and groundnut oils at similar rates. Sesame and groundnut oils may prove to be suitable for recommendation to smallholders but further work is required to define the rates of oil to be used.

Table 7. Numbers of Eggs and Holes per 100 Seeds and Numbers of Bruchid Adults on Three Occasions in Seeds of Cowpea Treated and Infested with *C. maculatus*.

	Nos. of eggs/ 100 seeds			Numbers of adults			Nos. of holes/100 seeds		
Treatment	18[a]	29	37	11	18	50	37	43	57
Groundnut oil	25.10a	69.00b	80.25c	4.50a	2.00a	0.25	4.60b	4.00c	3.00b
Sesame oil	20.33a	70.00b	81.50c	4.50a	1.50b	0.25	3.25b	8.00c	4.75b
Neem seed oil	29.50a	80.25a	140.25b	4.00a	3.50a	4.50	6.00b	19.00b	4.50b
Banana ash	14.50b	50.75c	343.75a	0b	1.20b	3.25	19.75a	73.00a	28.25a
Control	34.01a	84.75a	284.50a	3.50a	2.50a	2.50	15.25a	67.00a	17.00a
C.V. (%)	9.7	9.3	13.0	5.0	23.0	??.?	40	30	33

[a] number of days after infestation
Means in the same column followed by the same letter do not differ significantly from eachother at P = 0.05

Banana ash reduced egg deposition initially but egg laying increased in the later samplings producing a huge population by the end of the experiment. It may be that the ash treatment was not as effective as it would be in practice because the experimental material was frequently disturbed by sampling. In this connection it is worth noting the low counts of eggs and adults in the first sample.

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Review of Results of African Bean Drought Nursery in 1988 and 1989

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Abstract

The drought resistance characteristics of 25 bean cultivars and breeding lines were examined in 5 x 5 triple lattice experiments in Ethiopia and Kenya during 1988 and 1989 to identify genotypes suited to semi-arid areas of eastern and southern Africa. In 1988, A 422, A 410, G 2816 (and an ILCA tepary bean) produced the heaviest and most stable yields. In 1989, G 4830, A 422, P 133 and Harold Pink were best in Ethiopia and G 5201 performed well in Kenya.

Introduction

In most parts of eastern Africa, rainfall is the major limiting factor in crop production. The annual mean rainfall exceeds the potential evaporation from an open water surface on only 2 or 3 per cent of the land area (Dagg and Wangati, 1964). Distribution of rainfall is also erratic, usually starting late and ending early. In addition, the soils are shallow and have problems of compaction and surface crusting or sealing which lead to poor water infiltration and high runoff (Kidane, 1982). As a result, rainfed agriculture is a risky enterprise, being more so when the rainfall is below normal or when very long dry periods occur during the growing season.

Although, bean is adapted to relatively dry areas, its yield is greatly influenced by variation in amount and distribution of rainfall. Yield losses are particularly large when drought occurs at flowering or pod filling. Even though precise estimates are not available, bean yield losses in water stress areas can easily reach 50% or more. Further, the probability of yield loss due to drought influences the utilization of fertilizer and other inputs. Drought, therefore, is probably responsible for much greater economic loss than is appreciated.

Drought is the major constraint to bean production in many countries of Africa. In Ethiopia, bean is grown in the lowlands and rift valley areas, where drought is a major problem. Neighbouring countries produce bean under similar conditions. In these areas, bean production appears to be affected more by regional variation in the timing and total supply of rain than by other factors. Drought-tolerant cultivars can provide a cost effective means of reducing fluctuations in regional grain production in these and other areas lacking capital and increase the seasonal stability of food production for small-scale farmers.

To minimize the effects of moisture stress and increase crop production in drought prone areas, several countries in the semi-arid parts of Africa have launched breeding programs to develop drought tolerant cultivars of maize, sorghum, cowpea and other cereals. However, very little attention has been paid to bean.

In view of this a bean drought nursery subproject was approved by the Steering Committee of the Regional Programme on Beans for Eastern Africa in 1987 and research activity started in 1988 with the evaluation of early maturing bean cultivars provided by CIAT. Subsequently, during a workshop on drought resistance in bean, held in Harare 9-11 May 1988, it was decided that the sub-project should also include drought affected areas of southern Africa (Lesotho, Malawi, Botswana, Zimbabwe, Tanzania and Zambia). Thereafter, the original nursery was renamed the African Bean Drought Nursery, to be conducted on an Africa-wide basis.

The stated objectives of the nursery were to:

1. evaluate the performance of promising cultivars identified under drought conditions in Ethiopia and Latin America, across a wide range of dry environments in Africa;

2. develop a regional testing network for bean in Africa; and

3. examine and interpret genotypic responses to different drought patterns.

In this paper, we review only the highlights of the bean drought nursery from Ethiopia and Kenya. Results from Malawi and Tanzania have been descibed elsewhere (Mkandawire, 1990; Mkandawire and Gundo, in press; Tesha, in press)

Materials and Methods

Field experiments were conducted at five locations in 1988 and six in 1989 in Ethiopia (Table 1) and one location (Katumani) during the 1989 long rains in Kenya. The design used was a 5 x 5 triple lattice with 25 treatments and three replicates. The entries are listed in Tables 2 and 3. The plots were 4 rows 40 cm apart with 10 cm between plants within the rows, thinned to appropriate density after emergence. In Ethiopia the trials were sown during the first week of July (main rainy season) and, in Kenya in 1989, on 12 April. Data were collected from the two middle rows. The times to emergence,

Table 1. Characteristics of Locations of African Bean Drought Nursery in Ethiopia in 1988 and 1989.

Location	Latitude	Longitude	Altitude (masl)	Rainfall (mm)
Melkassa	8°24'N	29°21'E	1550	761
Wolenchiti	3°20'N	20°21'E	1400	550
Ziway	7°09'N	18°07'E	1650	600
Meiso	9°20'N	NR	1600	650
Kobbo[a]	12°02'N	39°38'E	1470	610
Sirinka[a]	15°50'N	39°47'E	1850	839
Babile[b]	9°10'N	NR	1350	550
Jijga[b]	NR	NR	1650	NR

[a] 1988 season only; [b] 1989 only; NR = not recorded

Table 2. Sources and Contributing Countries of Entries in African Bean Drought Nurseries in 1988 and 1989.

Treatment numbers	Entries	Countries of origin	Contributing programmes
1	G 5059	Brazil	CIAT
2	G 4446	Mexico	"
3	G 9025	-	"
4	BAT 477	CIAT	"
5	BAT 125	"	"
6	G 5201	Mexico	"
7	G 4830	Brazil	"
8	EMP 105	CIAT	"
9	A 54	"	"
10	BAT 798	"	"
11	Aguascalientes-13	Mexico	Ethiopia
12	EMP 175	CIAT	"
13	PAN 133	CIAT	"
14	AND 197	CIAT	"
15	ICA 15506	Colombia	"
16	A 410	CIAT	"
17	AND 338	CIAT	"
18	A 422	CIAT	"
19	BAT 338 1C	CIAT	"
20	Ex-Rico 23	-	"
21	Local check - farmers' cultivar		
22	Mexican 142		
23	Local check - standard bean cultivar		
24	Local check - standard cowpea cultivar		
25	Local check - farmers' cowpea cultivar		

flowering and maturity, stands after thinning and at harvest and plant height were recorded. Total dry matter was estimated. Seeds were weighed to determine yield per unit area and 100 seed weight adjusted to 10% moisture.

The data from each location were analyzed individually. In 1989, separate combined analyses were conducted for locations which received high and well-distributed rainfall and those which suffered moisture stress.

Results and Discussion

In both seasons, there were significant differences among entries for grain yield, seed size and days to flowering. In 1988, G-2816, A410, ICA7380 and Ex-Rico 23 were the heaviest yielders across locations (Table 4). In 1989, in dry conditions, Harold Pink, A-422, PAN-133, G 4830 and Aguascalientes 13 produced the best grain yields (Table 5), though differences among entries were not marked.

Table 3. Sources and contributing countries of entries in African Bean Drought Nurseries in 1989.

Treatment numbers	Entries	Countries of origin	Contributing programmes
1	Harold	USA	Lesotho
2	G 2816 (Flor de Mayo)	Mexico	CIAT
3	Ex-Rico 23	CIAT	
4	Rosa	-	Lesotho
5	A 422	CIAT	Ethiopia
6	AND 338	CIAT	"
7	NW 590	U.S.A.	Lesotho
8	A 410	CIAT	Ethiopia
9	ICA 15506	Colombia	"
10	AND 197	CIAT	"
11	G 5059 (Mulatinho)	Brazil	CIAT
12	G 8025		CIAT
13	G 4446 (Puebla 152)	Mexico	CIAT
14	BAT 477	CIAT	CIAT
15	PAN 133	CIAT	Ethiopia
16	Olathe	USA	Lesotho
17	EMP 175	CIAT	Ethiopia
18	BAT 338-1C	CIAT	"
19	Aguascalientes 13	Mexico	"
20	G 4830	Brazil	CIAT
21	Viva	-	Lesotho
22	EMP 105	CIAT	
23	A 54	CIAT	CIAT
24	BAT 798	CIAT	
25	G 5201	Mexico	CIAT

Table 4. Grain yields (kg/ha) of entries in African Bean Drought Nursery in Ethiopia in 1988.

	Locations[a]								
Entries	Kob	Mel 1st	Mel 2nd	Mie	Sir	Wol	Ziw	Mean	Rank
G 5059	924	3036	950	2056	720	1038	2622	1735	9
G 4446	753	4078	1038	2082	444	1409	2163	1712	10
G 8025	625	3318	1051	1883	392	1037	3060	1620	13
BAT 477	743	3594	812	2014	611	1265	2527	1652	12
BAT 125	789	2642	711	1602	465	1099	1913	1327	23
G 5201	588	2917	881	1458	525	1227	1888	1355	21
G 4830	682	3370	864	1343	661	1609	2743	1596	16
EMP 105	1546	3264	904	1510	438	1327	1422	1487	20
A 54	1176	2727	970	1468	450	1052	1594	1348	22
BAT 798	1043	3316	970	2700	810	1122	1940	1700	11
Aguascalientes-13	1581	3492	472	2318	924	1355	2161	1758	7
EMP 175	1305	3291	1094	1140	331	1137	2458	1537	18
PAN 133	2022	3332	821	1946	930	1193	2690	1848	5
AND 197	1116	3551	777	1671	273	1434	2489	1616	14
ICA 15506	659	3245	1135	1237	359	1042	1019	1242	24
A 410	1099	4087	1270	2226	1125	1457	3920	2169	2
AND 338	1195	3748	824	1222	1034	1163	1811	1571	17
A 422	1301	3873	1632	1879	864	1953	1910	1913	4
BAT 338 1C	794	3530	969	1585	672	1223	1907	1520	19
Ex-Rico 23	1264	4378	919	2032	680	1059	1987	1766	6
G 2816	1467	4588	1351	2701	850	2485	3167	2373	1
Mexican 142	810	3745	417	2094	639	1679	1835	1603	15
TVx 309-1G	1463	3368	295	2315	1314	2367	1028	1736	8
Blackeye Bean	1047	938	567	1278	319	975	423	792	26
ILCA 7380	2100	2457	1093	2799	1571	2049	1593	1953	3
Mean	1124	3387	911	1862	696	1385	2164		
S.E ±	71	90	48	62	55	58	132		
Rainfall (mm)	460	506	260	349	656	370	520		

[a] Kob = Kobbo; Mel 1st = Melkassa, 1st planting;
Mel 2nd = Melkassa, 2nd planting; Mie = Miesso; Sir = Sirinka;
Wol = Wolenchiti; Ziw = Ziwai

Combined analysis of the 1989 data revealed a significant difference only between the best (G 4830) and poorest yielders (ICA 15507) (Table 5). Under wet conditions (Melkassa and Ziway), A 422, A 140, G 5059, G 4446 and EMP 15 were the heaviest yielders but only G 5059 produced statistically greater yield than the check, Ex-Rico 23. In addition, the entries by locations interactions were not significant during the 1989 season, indicating similar rankings entries across locations. This is encouraging, because identifying genotypes with minimum interactions with environments and maximum stability (Allard and Bradshaw, 1964) is important, especially for regions where environmental fluctuations are considerable and means of modifying the environment are remote (Kombal and Mahmoud, 1978).

Cultivars such as A 422, G 4830, PAN-133 and Viva Pink produced good grain yields under both dry and wet conditions in 1989 (Table 5), indicating adaptation to both situations. Early maturing entries like Harold Pink and Aguascalientes-13 were among the highest yielders under dry-conditions (Table 3) probably due to drought escape.

Table 5. Grain Yields (kg/ha) of Entries in African Bean Drought Nursery in Ethiopia in 1989.

	Dry conditions						Wet conditions			
Treatments	Mel[a] 2nd	Wol	Mie	Bab	Mean	Rank	Mel 1st	Ziw	Mean	Rank
Harold Pink	1192	1499	770	562	1006	2	1875	3459	2667	24
G 2816 (Flor de Mayo)	752	1450	708	531	860	6	2824	3372	3098	14
Ex-Rico 23	810	797	447	625	670	18	2628	4145	3387	5
Rosa Pink	1109	787	582	645	781	8	2496	2769	2628	25
A 422	1330	1303	322	562	879	5	3227	4247	3737	2
AND 338	810	637	447	526	612	22	2111	3964	3038	17
NW 590	1260	746	644	437	772	9	2204	3655	2930	19
A 410	1046	1007	250	437	685	16	3142	4108	3624	5
ICA 15508	738	593	406	351	522	25	2023	3405	2714	22
AND 197	747	911	531	422	653	20	2281	4114	3198	12
G 5059 (Mulatinho)	625	1322	281	479	676	17	2725	5120	3922	1
G 6025	1113	780	510	458	715	12	2828	3819	3324	10
G 4446 (Puebla 152)	1035	1259	281	374	737	10	3357	4080	3719	3
BAT 477	767	1212	676	490	784	7	2068	4338	3203	11
PAN 133	762	1536	968	666	983	3	2117	4090	3104	13
Olathe	1117	949	374	375	703	13	2541	3630	3086	15
EMP 175	786	1005	249	479	629	21	2568	4090	3339	9
BAT 338-1C	875	1220	239	520	664	19	2143	3993	3068	16
Aguascalientes 13	746	1510	947	541	936	4	2070	3523	2796	21
G 4830	1159	1273	375	541	1087	1	2263	4517	3390	7
Viva Pink	1121	867	427	500	728	11	2692	4134	3413	6
EMP 105	958	728	197	354	553	24	2810	4551	3681	4
A 54	766	877	302	390	504	23	1987	3857	2922	20
BAT 798	1172	862	229	479	685	15	2357	3041	2699	23
G 5201	700	1061	489	518	392	14	2408	3547	2977	18
Mean	930	1033	507	490	740		2470	3903		
L.S.D. (P = 0.05)	285	423	779	501	512		884	1239	1062	
C.V. (%)	22	27	25	30	22		21	19	20	
Rainfall (mm)	260	270	347	247			530	545		

[a] Mel 2nd = Melkassa (2nd sowing); Wol = Wolenchiti; Mie = Meisso; Bab = Babile; Mel 1st = Melkassa (1st sowing); Ziw = Ziway

In both seasons, there were also significant differences among entries in seed size and number of days to flowering (Tables 6, 7 and 8).

At Katumani in Kenya in 1989, there were significant differences among entries in grain yields, time to flowering and seed size but growth was poor and grain yields were small, ranging from 279 to 618 kg/ha. G 5201 produced the largest grain yield and A 154 the poorest (Table 9).

Table 6. Days to Flowering of Entries in African Bean Drought Nursery in Ethiopia in 1988.

	Locations[a]							
Entries	Kob	Mel 1st	Mel 2nd	Mie	Sir	Wol	Ziw	Mean
G 5059	54	50	45	59	53	40	50	50
G 4446	54	48	45	56	55	41	51	50
G 8025	51	47	44	57	50	41	44	48
BAT 477	54	47	45	57	52	42	45	49
BAT 125	55	50	46	58	53	42	51	51
G 5201	53	48	45	57	53	42	50	50
G 4830	53	49	45	59	53	40	50	50
EMP 105	56	47	45	59	50	42	52	50
A 54	53	49	45	59	53	42	50	50
BAT 798	51	47	44	62	48	42	50	49
Aguascalientes-13	45	40	40	48	50	38	44	44
EMP 175	52	51	45	59	55	41	51	51
PAN 133	52	47	45	56	53	42	44	48
AND 197	45	42	40	51	46	36	47	44
ICA 15506	52	44	42	54	54	40	45	47
A 410	48	40	40	47	48	38	45	44
AND 338	50	43	40	54	53	38	47	46
A 422	46	42	41	51	50	38	47	45
BAT 338 1C	50	47	45	54	52	42	49	49
Ex-Rico 23	47	41	41	51	50	38	43	44
G 2816	47	38	40	47	44	38	45	43
Mexican 142	55	47	44	60	50	41	51	50
TVx 309-1G	63	64	62	68	51	44	45	57
Blackeye Bean	57	56	59	62	50	44	64	56
ILCA 7380	52	43	40	47	59	38	44	46
Mean	52	47	45	56	51	41	48	
L.S.D. (P = 0.05)	7	2	1	4	6	2	4	

[a] Kob = Kobo; Mel 1st = Melkassa, 1st planting; Mel 2nd = Melkassa, 2nd planting; Mie = Mieso; Sir = Sirinka; Wol = Wolenchiti; Ziw = Ziwai

Table 7. Weight of 1000 Seeds (g) of Entries in African Bean Drought Nursery in Ethiopia in 1989.

	Locations							
Entries	Mel 1st	Mel 2nd	Ziw	Wol	Mie	Bab	Jig	Means
Harold Pink	299	215	328	312	277	250	195	267
G 2816 (Flor de Mayo)	280	189	375	363	300	210	222	276
Ex-Rico 23	200	143	199	160	210	190	143	209
Rosa Pink	276	219	319	270	270	193	181	275
A 422	265	226	291	258	307	207	163	285
AND 338	413	290	504	372	337	340	237	377
NW 590	282	195	315	259	320	180	193	294
A 410	317	233	379	351	323	233	232	290
ICA 15506	463	205	572	422	443	267	300	282
AND 197	428	364	640	465	580	300	264	438
G 5059 (Mulatinho)	228	148	252	182	227	170	210	203
G 8025	198	140	205	149	220	167	204	183
G 4446 (Puebla 152)	285	182	336	241	320	190	257	259
BAT 477	209	189	247	189	230	183	187	205
PAN 133	172	144	233	141	193	180	160	175
Olathe	323	231	384	328	150	203	216	262
EMP 175	261	142	209	160	270	177	179	197
BAT 338-1C	154	133	189	165	167	190	158	165
Aguascalientes 13	348	221	437	450	490	307	265	364
G 4830	148	117	197	146	187	127	144	182
Viva Pink	250	191	275	247	237	177	167	221
EMP 105	179	162	255	181	213	183	152	190
A 54	172	156	246	195	207	180	146	186
BAT 798	176	173	219	176	227	177	128	182
G 5201	157	120	185	164	197	127	128	154
Mean								
L.S.D. (P = 0.05)	79.2	46.6	52.0	41.7	102	74.1	91.5	

[a] Mel 1st = Melkassa (1st sowing); Mel 2nd = Melkassa (2nd sowing); Ziw = Ziway; Wol = Wolenchiti; Mie = Miesso; Bab = Babile; Jig = Jijgab

In conclusion, although the results indicated that some genotypes have the ability to produce good grain yields when subjected to moisture stress, the trial should be repeated at a wider range of locations in the region using a larger number of parameters associated with tolerance to water stress.

Table 8. Days to Flowering of Entries in African Bean Drought Nursery in Ethiopia in 1989.

Entries	Locations[a] Mel 1st	Mel 2nd	Ziw	Wol	Mie	Bab	Mean
Harold Pink	43.0	34.7	37.0	33.7	30.0	51.0	38.2
G 2816 (Flor de Mayo)	43.0	36.3	38.3	32.3	35.0	41.3	39.4
Ex-Rico 23	43.0	37.7	43.0	36.0	42.0	45.7	41.2
Rosa Pink	43.0	31.0	39.7	36.0	35.0	43.7	41.4
A 422	45.0	37.7	42.0	37.3	38.0	42.0	40.3
AND 338	43.7	37.7	45.0	35.0	36.0	44.7	40.3
NW 590	43.0	34.7	38.6	35.0	36.7	43.0	38.6
A 410	43.0	36.0	43.3	38.3	40.7	54.0	40.3
ICA 15506	45.0	40.0	43.0	36.3	40.3	47.0	41.9
AND 197	43.3	38.6	45.0	34.0	36.3	42.7	39.8
G 5059 (Mulatinho)	49.7	43.7	46.0	44.3	51.3	53.3	48.1
G 8025	47.0	43.0	46.0	40.3	47.0	49.0	45.4
G 4446 (Puebla 152)	49.7	39.7	42.0	41.7	48.3	53.6	46.0
BAT 477	48.3	40.3	44.0	43.7	49.7	54.7	46.8
PAN 133	48.3	43.7	45.0	44.0	47.7	52.0	46.8
Olatha	43.0	34.7	38.7	32.3	31.3	44.0	37.3
EMP 175	48.7	45.0	46.0	45.3	50.7	40.0	46.0
BAT 338-1C	47.7	43.7	45.0	42.7	48.0	49.7	45.8
Aguascalientes 13	43.0	36.7	39.0	35.0	36.7	42.7	38.8
G 4830	49.0	43.3	44.0	43.0	48.0	50.7	46.3
Viva Pink	43.0	34.3	38.0	33.7	31.3	45.3	3[illegible].3
EMP 105	47.0	41.3	44.0	42.7	46.7	50.0	45.9
A 54	48.3	43.3	47.7	41.7	47.0	52.3	46.7
BAT 798	47.7	29.7	47.3	41.0	51.7	54.0	45.2
G 5201	49.0	43.7	47.7	43.3	48.3	54.7	47.8
Mean	44.1	39.6	42.1	38.7	42.1	48.1	
L.S.D. (P = 0.05)	1.6	2.6	4.8	3.4	7.7	9.9	

[a] Mel 1st = Melkassa (1st sowing); Mel 2nd = Melkassa (2nd so
Ziw = Ziway; Wol = Wolenchiti; Mie = Miesso; Bab = Babile

Future Research

The experiments will be carried out for one more season as previously planned and the number of entries reduced to a manageable size. In Phase II of the programme, studies will be conducted to identify the traits associated with drought resistance or tolerance and incorporate them into a breeding programme.

Table 9. Characteristics of Entries in African Bean Drought Nursery at Katumani in Kenya in 1989.

Entries	Grain yields (kg/ha)	Days to flower	Weight of 1000 seeds (g)
Harold Pink	494	44.7	215
G 2816 (Flor de Mayo)	416	44.0	250
Ex-Rico 23	470	43.3	179
Rosa Pink	448	42.3	203
A 422	404	46.0	195
AND 338	598	44.7	163
NW 590	516	45.7	157
A 410	480	45.0	191
ICA 15506	408	46.0	197
AND 197	455	44.7	192
G 5059 (Mulatinho)	290	37.0	359
G 8025	570	47.0	180
G 4446 (Puebla 152)	545	44.3	214
BAT 477	290	38.3	484
PAN 133	361	40.0	464
Olathe	564	36.3	319
EMP 175	419	38.3	470
BAT 338-1C	455	38.7	250
Aguascalientes 13	495	43.0	160
G 4830	354	39.0	180
Viva Pink	600	35.3	327
EMP 105	413	39.7	168
A 54	279	39.3	346
BAT 798	300	45.0	132
G 5201	619	37.7	145
L.S.D. (P = 0.05)	203.8	5.6	72.1

The parameters to be collected, will include: leaf water potential; stomatal resistance; leaf extension rate; leaf area index (LAI); rooting density and pattern; heat tolerance; and soil water potential.

Line source sprinker irrigation system will be used to monitor the desire level of water stress required in testing genotypes for their stress tolerance, since rainfall interferes with evaluation during the rainy season.

Two sowing dates in a single season will also be continued to obtain different patterns of stress in the same season.

Monitoring tours will be initiated to assess progress and exchange ideas and experiences of researchers of cooperating countries in the region.

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Preliminary Studies of Biological Nitrogen Fixation by Haricot Bean on Two Soil Types in Hararghe, Ethiopia

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Abstract

Bean (Phaseolus vulgaris) is important as a source of protein and cash for smallholders in Ethiopia. Yields are very poor because of scarcity of fertilizers. Bean is produced mainly in association with other crops, but there is increasing interest in pure stands. Studies are in progress of the need for inoculation with Rhizobium in different cropping systems. There were significant (P = 0.01) differences among 19 strains of rhizobia for nodule number and plant fresh weights of bean in pure stand and in bean dry matter weight in association with sorghum. Application of nitrogen depressed nodulation and variation in nodulation has been demonstrated among bean cultivars. Native rhizobia strains appear to be ineffective. Tests are proposed of a wider range of Rhizobium strains and bean genotypes in pure stand and in association.

Introduction

In Ethiopia, haricot bean (*Phaseolus vulgaris*) is most common in altitudinal ranges of 1,400-2,000 masl, in pure stand in the Rift Valley and in association with other crops in other areas. It is considered both a cash crop and a protein source. Economically, it is an important export commodity. The yield level is estimated to be 650 kg/ha (Amare, 1987). This is attributed among other reasons to the cultivation of beans on soils poor in nutrients, previously used for growing other crops. Amare (1987) reported that bean responds to N when grown on poor soils. Previous studies (Dagnew, 1981; Amare and Birhanu, 1984) indicated the benefits of growing bean in association with cereals. Expected benefits from nitrogen fixation and improvements in soil fertility have not been realized. Moreover native rhizobial strains appear ineffective in nitrogen fixation (Amare, 1987; NSSP, 1989).

In Ethiopia, haricot bean is planted on all types of soils, but yields are poor, since the crop requires high fertility. The same has been reported in Uganda (Mukas, 1970), where bean also nodulates poorly (Stephens, 1967; Acland, 1971; Anderson, 1973). Previous studies of inoculation in Ethiopia were based on surveys outside the main bean producing areas (Amare, 1987). Inoculation is not practised by farmers in Ethiopia. The need for inoculation and the benefits of symbiotic nitrogen fixation are realized by farmers in eastern Africa. However this was not verified for cropping systems in eastern Africa in general and Ethiopia in particular.

Experiments were therefore initiated in 1989 to study the role of nitrogen fixation by haricot bean in different cropping systems in the context of bean improvement in eastern Africa with the specific objectives of:

1. studying the effects of bean on the yield of sorghum;
2. studying the effects of sorghum on yield of bean;
3. comparing bean yields in association and pure stand;
4. comparing nodulation of bean in association and in pure stand;
5. comparing nodulation of bean by different rhizobial strains;
6. studying the effects of N on bean nodulation and yield;
7. investigating genotypic variation in nodulation and yield;
8. conducting a survey of nodulation in farmers' fields.

Materials and Methods

Surveys of Farmers' Fields

Twenty five farms (Figure 1) were surveyed in August, 1989. The farms were selected randomly to represent different agro-ecological zones and soil conditions. From each farm cultivating haricot bean, six random plants were dug, soil particles carefully separated from the roots and nodules examined for position on roots, color, size and number, according to CIAT (1988).

Greenhouse Experiment

Nineteen *Rhizobium* strains from CIAT were used to inoculate seeds of *P. vulgaris* line A 422 sown in earthen pots in a randomized block design with four replications. The pots were each filled with 4 kg of Alemaya series, degraded Haplustalf soil deficient in N. A basal dressing of P_2O_5, KCl, MgO, borax and $ZnSO_4$ was applied in powder and solution forms. The soil was equilibrated with sufficient water to ensure uniform moisture. Subsequent watering kept soil moisture at 75 per cent of field capacity. Five clean seeds of A 422 were sown in a circular arrangement in each pot. Plants were inoculated at the three leaf stage with one teaspoonful of peat-based inoculant placed near the stem base and covered with clean sterile sand. Nodule volumes and numbers were recorded on three plants at fifty per cent flower. The fresh and dry (following drying at 60^o for 48 hours) weights of the tops were recorded. Total N was determined by the Kjeldahl method.

Field Trials

Four trials were conducted at Alemaya and Hamaressa in 1989. The soil characteristics of the two sites are summarized in Table 1.

Rainfall distribution of the area is bimodal. The small rains begin in February extending to the first week of May. A dry spell ensues towards the end of May and the whole of June prior to the large rains which start in July. Long term averages show annual total rainfall to be 810 mm, 60% of which falls between July and September. Temperature variations encountered in the area also need to be considered. In valley bottoms, cold temperatures result in frost, which can damage late maturing haricot bean (personal observation).

The trials were all randomized complete block designs with three replicates. Except where otherwise indicated, haricot bean was sown in rows 40 cm apart with 10 cm between plants along the rows in a plot size of 4.5 x 4.4 m. Nodulation was examined on each occasion according to CIAT (1988) on 6

Figure 1. Distribution of farms sampled for nodulation and soil characteristics in Harargue in 1989.

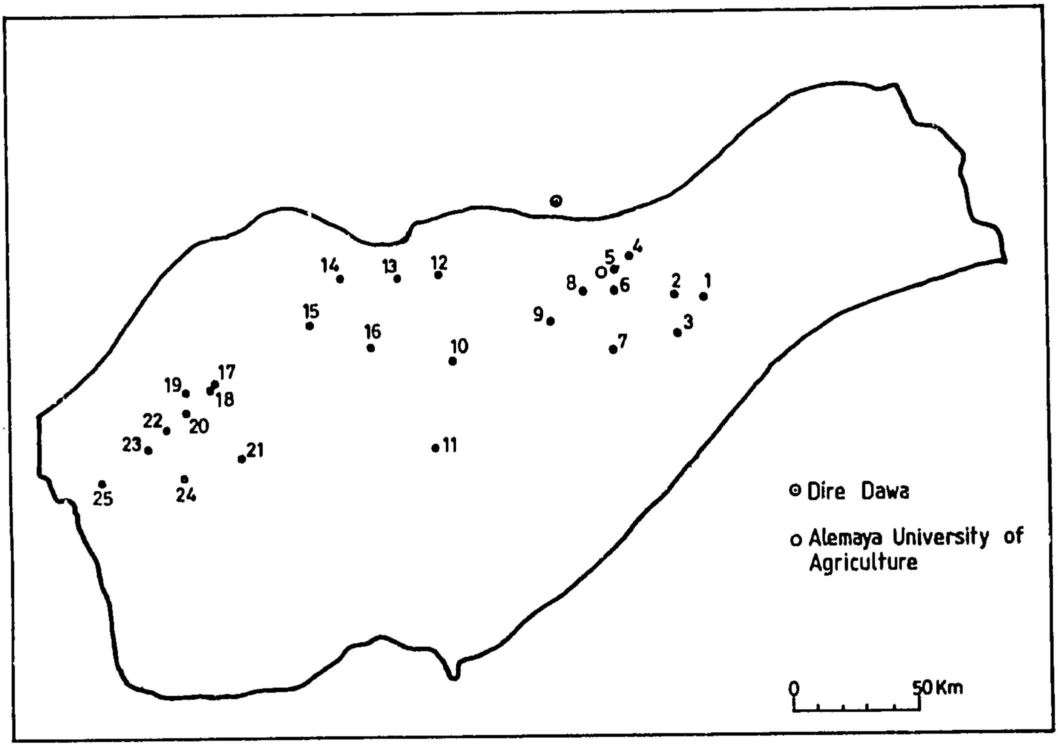

Table 1. Soil Characteristics of the Trials Sites.

Trial location	Soil type	Texture	OM %	pH (in H_2O)	P (ppm)	AWC (mm/cm)
Alemaya	Typic Pellustert	Clay	1.6	7.9	7.5	42.8
	Haplustalf (degraded)	Sandy loam	1.5	6.8	3.1	27.0
Hamaressa	Rhodustalf	Clay	2.4	6.2	1.8	32.0

carefully dug plants per plot. The weights of grains harvested (bean and sorghum) were recorded.

In one trial, four haricot bean cultivars (Mexican 142, Ex-Rico 23, Black Dessie and a local cultivar) and two sorghum cultivars (ETS 2752 - tall - and IS 9333 - short) were compared in pure stand and in association on a Rhodustalf. Sorghum was sown on 29 April and bean three weeks later. The sorghum was in rows 80 cm wide with 20 cm between plants. Nodulation was examined at mid flowering.

The effects of N were examined in three trials. In two trials (on a Rhodustalf and Pellustert), four levels of N (0, 23, 46, 69 kg/ha) were banded under the seed during planting, ensuring seed and fertilizer separation. The haricot bean cultivar was Alemaya White. Nodulation was assessed at ten day intervals.

Another trial examined nine haricot bean cultivars and lines from National Yield Trials with and without 23 kg/ha N applied in the form of urea at sowing. Nodulation was assessed at ten day intervals.

Results and Discussion

Survey of Farmers' Fields

Haricot bean production was restricted to altitudes below 2,330 masl (Table 2, Figure 1), above which other legumes such as faba bean and field pea assumed importance. Vertisols, Alfisols, Oxisols and Entisols were the predominant soil types for haricot bean production. Specific deficiency symptoms reflected the variability in the soils. Haricot bean grown on slightly acidic soils tended to be least vigorous.

Organic matter ranged from 1.1 to 2.9% with a mean of 1.7% which is extremely poor and indicates a need for nitrogen. Low available P was associated with low pH values - some fields with high P had been fertilized during the current season. Haricot bean occurred in pure stands in only six fields. In the remaining fields, bean was associated with other crops - mainly sorghum in low rainfall areas and chat, coffee or maize where rainfall was

Table 2. Nodulation Survey of Haricot Bean in Hararghe, Eastern Ethiopia.

Location No.	Location Name	Altitude (m)	Rainfall (mm)	pH	Soil type	OM %	P (ppm)	System	Cultivar	Nodules No.	Nodules Size	Nodules Color	Nodules Site
6.	Sherif Kalid	1890	810	6.1	Alfisol	1.2	8	ASS	Kenya	38	S-M	pink	TR
4.	Dire Teyara	2020	830	6.5	Alfisol	1.5	10	ASS	Kenya	31	M	white	TR
2.	Woldya	1430	750	7.3	Entisol	1.6	12	ASS	White	84	M-L	pink	RH
3.	Erervalley	1360	680	8.5	Entisol	1.5	8	PS	White	35	S	white	RH
1.	Babile	1650	700	7.3	Alfisol	1.1	9	ASS	White	41	S-M	white	TR
7.	Fedis	1780	820	6.2	Alfisol	1.4	8	ASS	Kenya	27	L	pink	TR
8.	Muleta	2100	850	6.9	Alfisol	1.7	11	ASS	Kenya	16	L	pink	TR
9.	Kurfachele	2130	870	7.3	Vertisol	12.1	14	ASS	Kenya	78	L	pink	TR
10.	Bedeno Tokuma	1910	1320	6.2	Alfisol	1.5	6	ASS	White	36	S-M	white	RH
11.	Burka Tirtina	1720	850	7.8	Vertisol	1.7	10	ASS	Kenya	80	S-L	W/P	TR
12.	Kobo	2300	930	6.8	Entisol	1.8	12	PS	Kenya	46	S-M	white	RH
13.	Boreda	2330	980	8.1	Vertisol	2.1	15	PS	Kenya	2	M-L	white	RH
14.	Feresama	1780	830	7.5	Vertisol	1.9	13	ASS	Kenya	75	M-L	white	RH
15.	Amensis	1830	1100	8.1	Vertisol	2.2	9	ASS	Kenya	64	S-L	white	TR/RH
16.	Melkabello	1650	870	6.5	Alfisol	1.3	8	ASS	Kenya	18	S-M	white	TR
17.	Bedessa	1720	1250	6.3	Alfisol	1.4	7	ASS	Kenya	22	S-M	white	TR
18.	Bedessa	1710	1250	7.6	Vertisol	1.8	12	PS	Kenya	58	M-L	white	RH
19.	Bedessakutor	1960	1250	8.1	Vertisol	2.3	13	PS	Kenya	65	S-L	white	RH
20.	Wachu	1780	1250	8.3	Vertisol	1.7	9	ASS	Kenya	54	S-M	W/P	RH
21.	Boke Tiko	1960	820	7.6	Mollisol	2.9	16	ASS	Kenya	62	S-M	white	RH
22.	Gelmso	1820	1250	7.8	Vertisol	1.8	12	PS	Kenya	73	S-M	W/P	TR
23.	Kutur 16	1870	1250	5.5	Oxisol	1.2	7	ASS	Kenya	16	M-L	white	RH
24.	Dereku No. 29	2030	1250	5.3	Oxisol	1.5	9	ASS	Kenya	18	M-L	white	RH
25.	Micheta	2120	1250	5.6	Oxisol	1.7	8	ASS	Kenya	19	M-L	white	RH
5.	Finkile	1980	810	6.5	Alfisol	1.6	19	ASS	Kenya	25	S-M	white	TR

.ASS = in association; PS = pure stand; S = small; M = medium size; L = large; TR = tap root; RH = root hairs; numbers refer to locations in Figure 1

sufficient. Bean in association with sorghum or maize is broadcast when the cereals are knee-high. With chat or coffee, bean is in the alleys. The only cultivars were Kenya and White. Nodule numbers ranged from 16 to 84, tending to be more on Vertisols and less on Oxisols and Alfisols.

Tremendous variability was observed in nodule size, color and position on roots. Small, medium and large nodules were found on the same plants. The larger nodules were on (or near) the taproots: the smaller and medium-sized nodules mostly appeared on root hairs. Except on very few fields, nodules were white in color. Where pinkish nodules occurred they were relatively large.

Native rhizobia were capable in all cases of infect...g the host but were not sufficiently effective to produce leghaemoglobin. Variation in populations and infectivity also influence the number, size and effectiveness of the nodules. Although haricot bean had been grown continuously on the farms surveyed, inoculant had never been used. Previous studies (Amare, 1988) indicate that inoculation with rhizobia increases the yield of haricot bean but inoculation without adequate phosphorus and micronutrients will not produce substantial N fixation (Macartney and Watson, 1966; Stephens, 1967; Keya, 1977).

The ineffectiveness of native rhizobia may be due to their genetic make-up, which has been also observed by other investigators in eastern Africa (Denarie, 1968; Souza, 1968), or to adverse edaphic conditions. In high rainfall areas, haricot bean showed symptoms of zinc and molybdenum deficiency whereas, in soils with high pH values, lime-induced iron chlorosis was observed.

Besides adverse soil conditions and variations in weather, biological factors also influence nodulation and N fixation. Parasites, predators, antibiosis and other organisms that may affect the symbiosis should be considered. In fields where root knot nematodes were observed, nodulation was poor. This could be due to interference and competition for nodule sites. Earlier reports confirm the prevalence of nematodes on haricot bean (Ngunda, 1973; Habtu, 1987).

Greenhouse Experiment

There were significant differences (P = 0.01) among *Rhizobium* strains in nodule numbers and fresh weights of the tops of A 442 (Table 3). Tap and lateral roots of inoculated plants were better nodulated than uninoculated plants, which produced comparatively high proportions of ineffective white nodules. The ineffectiveness may be due to antibiotics inhibiting native strains from producing pink nodules (NSSP, 1989). Exotic strains produced effective nodules although numbers varied tremendously. This clearly indicates that inoculation with suitable strains can improve the N fixation ability of haricot bean.

Uninoculated plants had the smallest fresh weights. Fresh weight was improved by 30 percent by inoculation with strain 274 compared with uninoculated plants. Similar observations were made in Kenya (Bumps, 1957). It is evident that there is little difference among strains in dry matter produced and little relationship with nodulation: the strain which gave the least number of nodules produced 47 percent more dry matter than the uninoculated treatment. Similarly, differences among strains in total N in the tops did not differ significantly, but strain 632 fixed more than three times the total N than uninoculated plants. Thus, profuse nodulation may not substantially increase the amount of N fixed in the host (Keya, 1977). However, the N remaining in the soil from nodule senescence and excretion may be greater from plants with more effective nodules.

Intercropping

In the intercropping trial, the number and volume of nodules of haricot bean were unaffected by cropping systems (Table 4). All entries were infected but the nodules in all cases were ineffective. Black Dessie produced the most nodules with the largest volume in both pure stand and in association with ETS 2752 (tall) sorghum. Nodule number and volume were least in Ex-Rico 23 in association with ETS 2752, possibly due to low light intensity restricting N fixation.

Table 3. The Effect of Inoculation with Rhizobia on Nodule Number and Volume, Fresh and Dry Matter and Total N Yield of A 422 in a Greenhouse Test.

Strains	Nodules: Number	Nodules: Volume (ml)	Fresh weight[a]	Dry matter[a]	N[a]
274	591.5	8.80	82.15	14.09	0.154
348	572.0	2.27	74.26	12.99	0.175
876	536.8	9.22	78.45	13.95	0.126
57	536.5	10.05	79.54	14.74	0.161
151	492.0	8.52	75.95	13.00	0.140
Uninoculated	473.5	8.27	57.20	8.02	0.061
113	466.0	6.25	113.53	14.53	0.123
899	448.8	8.68	77.20	14.72	0.119
112	435.8	6.75	70.07	13.95	0.129
5	405.5	6.25	76.85	13.59	0.108
639	398.5	7.60	81.77	14.17	0.119
613	393.3	6.75	73.43	13.89	0.105
45	392.8	6.62	65.19	12.39	0.126
166	395.8	7.02	74.39	14.12	0.126
2	375.3	6.05	62.22	11.43	0.119
144	375.0	6.27	68.66	13.11	0.119
640	356.5	7.40	65.69	13.00	0.115
652	347.5	6.47	78.02	14.48	0.109
7001	345.5	5.32	66.40	14.00	0.122
632	227.3	6.85	79.04	15.03	0.198
S.E. ±	40.96	0.93	4.41	1.15	0.022
C.V. (%)	19.1	6.4	11.0	16.6	35.2

[a] g/3 plants

There were significant interactions between cropping systems and entries for top dry matter yields. Black Dessie produced more dry matter in association with tall sorghum than in either pure stand or in association with short sorghum, suggesting that this late-maturing cultivar is tolerant of shading. The top dry matter yields of the other entries did not appear to be affected by cropping system.

The grain yields of the local cultivar and of Ex-Rico 23 were much less in association with sorghum than in pure stand (Table 5). In contrast, the yield of Black Dessie was much greater in association with short sorghum than in pure stand or in association with tall sorghum and the yields of Mexican 142 were little affected by cropping system. This suggests the occurrence of cultivar differences in suitability for association with sorghum. Sorghum yields were reduced in association with haricot bean, perhaps attributable to competition for nutrients, water, light or rooting space (Kurtz *et al.*, 1952; Pendleton *et al.*, 1963; Enyi, 1973). Land Equivalent Ratios (LERs) indicated considerable yield benefits of associated cropping over pure stands of haricot

Table 4. Nodule Numbers and Volumes and Top Dry Matter Yields of Haricot Bean in Pure Stand and Associated with Sorghum on a Rhodustalf at Hamaressa in 1989.

	Nodule number				Nodule volume (ml)				Dry matter (g/6 plants)			
Entries	Pure stand	Ass. 2752	Ass. 9333	Mean	Pure stand	Ass. 2752	Ass. 9333	Mean	Pure stand	Ass. 2752	Ass. 9333	Mean
Black Dessie	187.0	163.0	86.0	145.3	3.03	3.60	1.70	2.77	18.1	39.3	9.0	22.1
Ex-Rico 23	99.3	49.6	131.3	93.4	2.53	0.46	1.60	1.53	17.3	12.5	13.5	14.4
Mexican 142	81.6	77.3	61.6	73.5	1.60	1.23	1.36	1.39	15.8	21.1	25.0	20.6
Local	96.6	104.0	141.3	113.9	1.60	1.43	1.50	1.51	14.9	14.5	10.4	13.3
S.E. ±		8.67		37.99		0.633		0.686		5.54		4.94
C.V. (%)		18.7				61.0				54.3		
Mean	116.1	98.4	105.0		2.19	1.68	1.54		16.5	21.9	14.5	
S.E.		36.13				0.49				5.09		

Table 5. Grain yields and LERs of Haricot Bean and Sorghum in Pure Stand and Associated on a Rhodustalf at Hamaressa in 1989.

	Haricot bean (kg/ha)				Sorghum (kg/ha)			LER		
Entries	Pure stand	Ass. 9333	Ass. 2752	Mean	Ass. 9333	Ass. 2752	Mean	Ass. 9333	Ass. 2752	Mean
Local	1653	775	1562	1169	1093	1741	1417	1.23	1.75	1.49
Ex-Rico 23	2999	2223	1854	2039	1253	1931	1592	1.61	1.51	1.56
Mexican 142	2823	2725	2556	[illegible]541	1151	1990	1571	1.76	1.82	1.79
Black Dessie	1656	2334	1386	1860	1033	1769	1401	2.13	1.65	1.89
Pure stand					1445	2166	1806			
S.E. ±		439.7		324.1	113.6		150.5			
C.V. (%)		37.8			16.5					
Mean	2283	2014	1840		1195	1919		1.68	1.68	
S.E. ±		251.8			256.7					

bean and sorghum. The best LER (more than 2) was produced by Black Dessie in association with short sorghum, reflecting the compatibility of these two genotypes.

In this experiment, sorghum yields did not benefit from N fixation by haricot bean, perhaps due to the ineffectiveness of native *Rhizobium* strains. Previous work (Agbòola and Fayemi, 1972; Chowdhury and Misangu, 1979) has shown that N fixed by inoculated legumes is used by associated cereals thereby increasing cereal yields. Other studies (Henzell, 1970) indicate the absence of any appreciable direct flow of N from legumes to associated crops: cereals do not benefit from associated beans sown at the same time, unless the nodules are formed early and senesce to release the fixed N. Future studies of intercropping systems need to consider aspects of inoculation, planting dates of the associated bean, rotations and sequential cropping to understand the benefits of N fixation.

Effects of Nitrogen on Nodulation and Yield

On an Alfisol at Hamaressa, haricot bean nodule numbers and volumes increased up to 35 to 45 days after sowing then declined (Table 6). Between 25 and 55 days after sowing nodule numbers and volumes decreased significantly with increasing levels of N. Nodulation was not inhibited even at high levels of nitrogen but, in all cases, the nodules were ineffective.

Table 6. The Effects of Nitrogen Application on the Nodule Numbers and Volumes of Haricot Bean on an Alfisol at Hamaressa in 1989.

Days after sowing	Nodule numbers N (kg/ha)						Nodule volumes (ml) N (kg/ha)					
	0	23	46	69	Mean	S.E.	0	23	46	69	Mean	S.E.
25	80	48	36	12	44	12.82	0.4	0.2	0.1	0.1	0.2	0.05
35	83	64	37	19	50	10.93	0.70	0.43	0.33	0.27	0.43	0.07
45	77	53	33	17	45	5.24	0.77	0.57	0.30	0.20	0.46	0.03
55	72	46	25	11	38	7.01	0.70	0.50	0.20	0.20	0.40	0.06
65	63	43	20	8	33	5.22	0.50	0.30	0.20	0.10	0.27	0.01
75	41	33	15	5	23	3.41	0.40	0.20	0.20	0.10	0.22	0.01
Mean	69	47	27	12			0.57	0.33	0.21	0.15		

Nodule numbers and volumes were much greater on the Vertisol at Alemaya (Table 7) but, although they decreased with increasing levels of N, the differences among treatments were not significant and nodulation was never totally curtailed. Nodule numbers and volumes reached maxima much later during the growth cycle (60 days after sowing) on the Vertisol than on the Alfisol.

The application of N had no significant effects on grain yields. Yields of haricot bean grown on the Vertisol (2407 kg/ha) were nearly twice as much as yields on the Hamaressa Alfisol (1251 kg/ha), even without N. However, on the Alfisol, yields declined much sooner with successive increments of N (1056, 1407, 1334 and 1210 ±58.4 kg/ha for the four N treatments) than on the Vertisol, where yield responses continued up to 46 kg N/ha (2107, 2266, 2749 and 2509 ±147.3 kg/ha). These preliminary studies indicate the need for fertilizer application if haricot bean production is to be successful in Hararghe, particularly when grown in pure stands.

On a degraded Alfisol, nodules were fewer where N was applied and there were significant differences among nine bean lines and cultivars in nodule

Table 7. The Effects of Nitrogen Application on the Nodule Numbers and Volumes of Haricot Bean on a Vertisol in 1989.

Days after sowing	Nodule numbers						Nodule volumes (ml)					
	N (kg/ha)						N (kg/ha)					
	0	23	46	69	Mean	S.E.	0	23	46	69	Mean	S.E.
30	151	117	108	38	103	31.2	2.3	1.2	0.9	0.2	1.15	0.75
40	183	172	143	82	145	37.8	3.2	2.1	1.5	0.5	1.82	0.22
50	320	254	203	201	244	98.8	8.9	4.7	7.8	2.9	6.07	2.19
60	338	466	275	251	332	78.5	9.5	11.1	8.3	5.2	8.52	3.12
70	307	284	241	181	253	99.3	10.2	5.3	6.0	4.6	6.52	2.41
80	269	240	192	154	213	125.4	5.8	8.0	3.3	7.0	6.03	2.32
90	99	65	47	36	61	16.1	1.1	1.0	0.7	0.6	0.85	0.24
Mean	238	228	172	134	193		5.9	4.8	4.1	3.0	4.45	

numbers at 40 days after sowing when N was applied and at 30, 40, 50 and 70 days after sowing without N (Table 8). Again, all the nodules were ineffective.

Table 8. Nodule Numbers and Yields (kg/ha) of Nine Haricot Bean Cultivars and Lines Grown With and Without Nitrogen on a Degraded Alfisol at Alemaya in 1989.

Entries	Nitrogen							No nitrogen							Grain yields (kg/ha)	
	Days after sowing							Days after sowing								
	30	40	50	60	70	80	Mean	30	40	50	60	70	80	Mean	+N	-N
Local White	11	44	46	111	100	40	58	188	245	257	221	182	87	296	2479	1557
A 176	13	16	33	137	135	61	65	93	116	172	191	107	95	129	2557	1760
A 265	28	43	43	162	116	12	67	210	263	283	310	251	72	248	2678	1834
Mulatinho A	22	27	45	76	65	29	44	185	218	277	380	167	96	220	2069	1934
A 62	20	21	27	52	47	32	33	50	76	79	84	38	29	59	2728	1423
BAT 65	48	52	82	160	125	64	88	171	205	272	295	173	102	203	2727	1598
Carioca	36	59	80	186	120	95	96	215	272	279	299	182	127	224	2883	1669
997-CH-173	29	47	95	201	107	104	97	80	83	131	213	95	74	112	2947	2668
A 445	23	37	64	238	165	83	101	205	267	326	343	179	143	243	3103	2668
Mean	25	38	57	147	108	57	72	155	190	230	259	152	102	181	2730	1831
S.E. ±	12.5	9.5	24.8	49.3	50.4	39.2		21.6	7.8	33.7	39.7	27.3	57.8			

In the same trial, there were significant differences among entries in nodule volume at 40 and 80 days after sowing where N was applied and 40, 50 and 60 days after sowing without N (Table 9).

Table 9. Nodule Volumes of Nine Haricot Bean Cultivars and Lines Grown With and Without Nitrogen on a Degraded Alfisol at Alemaya in 1989.

	Nitrogen							No nitrogen						
	Days after sowing							Days after sowing						
Entries	30	40	50	60	70	80	Mean	30	40	50	60	70	80	Mean
Local White	0.09	0.25	0.33	3.3	1.3	2.8	1.34	2.7	6.2	7.4	6.3	5.8	2.6	5.1
A 176	0.09	0.10	0.30	2.7	2.8	2.0	1.35	1.4	2.7	1.7	4.0	5.3	6.1	3.5
A 265	0.20	0.23	0.28	2.8	4.7	0.3	1.41	2.0	3.9	6.5	4.9	2.9	5.7	4.6
Mulatinho A	0.31	0.20	0.47	2.7	2.7	3.3	1.61	2.8	3.5	3.8	3.0	3.8	1.9	3.1
A 62	0.16	0.10	0.13	2.2	1.8	0.8	0.86	0.4	1.5	1.9	3.0	1.8	3.8	2.0
BAT 85	0.43	0.17	1.27	3.4	4.3	1.2	1.79	2.0	2.6	2.2	4.7	3.1	4.1	3.1
Carioca	0.23	0.40	0.53	2.7	5.9	1.9	1.94	3.1	5.4	6.3	10.0	6.4	10.9	7.0
997-CH-173	0.23	0.27	0.87	7.1	5.7	5.9	3.34	0.7	1.2	7.1	10.8	5.1	4.2	4.8
A 445	0.13	0.23	0.97	9.9	5.9	4.2	3.55	3.8	5.5	5.6	8.9	7.2	8.1	6.5
Mean	0.20	0.21	0.57	4.0	3.9	2.5	1.89	2.1	3.8	4.7	6.1	4.6	5.2	4.4
SE (+)	0.13	0.06	0.35	2.31	1.63	1.12		0.71	1.12	1.44	1.34	1.22	2.03	

Differences in grain yields among the 11 entries were not significant (Table 8). The largest yield increase (48%) due to N application was obtained from A 62. Mulatinho-A showed the smallest yield response (7%). The absence of yield differences among entries confirms the need for N fertilization. Notwithstanding, inoculation with rhizobia and ability to fix N will benefit the N status of these soils. Subsequent trials need to include some of these entries with and without inoculation in pure stands and association with sorghum.

Recommandations and Future Research Needs

These preliminary results indicate the need for inoculation of haricot bean. Promising *Rhizobium* strains will be tested in the field in pure stand and in association with sorghum. Selected bean genotypes will be grown under a uniform canopy of sorghum to evaluate their nodulating capacity. Greenhouse experiments will be continued to study the effect of nutrients on nodulation and nutrition of haricot bean. These trials will be conducted for a further two years.

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SUMMARY OF DISCUSSIONS

Smithson and Gridley

The purposes of the AFBYAN are to disseminate improved cultivars among NPs and to compare performance in different agro-ecological zones including Latin America, in order to assess the importance of environmental features in determining yields. Beside associations between rainfall and diseases, there are many other factors to consider.

Musaana and Opio

For seed production, it is important to ensure that clean seeds are used by quality tests. In Uganda the social costs of CBB are large because every seed production attempted has become infected to the extent that it is no longer possible to produce seed. It is a very serious problem.

In the studies, spreader rows and inoculation are used in an attempt to obtain uniformly severe levels of disease.

It is the general comment from the house that the future plans are very ambitious.

Sengooba and Male-Kayiwa

Future plans are more realistic than those for the CBB subproject.

Habtu Assefa

A set of internationally accepted standard differential varieties was used for determining races of rust. In crop loss assessment trials, the crop was artificially inoculated.

The regression equation developed, may not reflect all farmers' conditions but does cover widely different levels of disease.

In disease loss assessment other diseases were controlled by treating the seed.

The time span of future work is three years.

The expression of partial resistance will be determined by measuring such characteristics as incubation period and sporulation.

It is important to include other countries in the region in assessing disease losses due to rust.

Owera

The ELISA method is cheaper than immuno-diffusion in virus identification and kits have been developed to screen materials in the field.

Necrotic strains of BCMV were not collected during the survey in Ethiopia. The reason is not clear.

There were some problems with cross reaction, but over time it was possible to eliminate the effect.

It may not be possible to screen all seed samples before sowing, even in breeding work, but for special studies this can be done.

It is not practical to identify BCMV strains in insect vectors but it is relatively easy in seed or growing plants.

Kidane Georgis

The importance of other environmental factors in enhancing or masking drought effects was discussed. Concern was expressed about temperature effects on drought tolerance. It was suggested that evaluation be done under controlled conditions in a screen house. It was pointed out, however, that the importance of root morphology to drought tolerance made pot experiments undesirable. It was suggested that statistical procedures are available to separate the effects of the various factors, such as temperature, rainfall and diseases from those of drought.

As no drought stress occurred in some of the trials their means were very high relative to the overall mean. It was pointed out that these high yields greatly influence the overall means of the entries that do especially well in good environments. It was suggested that the data from high yielding trials be weighted to eliminate their distortive effects or that they be excluded from the analysis so that only stress environments are considered.

Selection based on differences in leaf size, pubescence, root size or leaf temperature was discussed and it was suggested that evidence may be lacking on the value of basing selection for drought tolerance on such characteristics.

It was pointed out that responses of entries in the drought nursery agreed with those observed at CIAT.

There was no discussion of the proposed plans for future research.

Mitiku Haile

It was suggested that total N should be used rather than 70N when evaluating nitrogen fixation. The value of nodule counts relative to the use of acetylene reduction was questioned but apparently the equipment for acetylene reduction is not available to the research project.

Further collection, isolation and evaluation of native strains was recommended and it was agreed that this will be a future activity. The value of inoculating with single strains relative to mixtures of strains was questioned and it was agreed that it should be investigated.

The feasibility of inoculating seed to be sold to farmers was discussed.

The speaker pointed out that several African countries are producing rhizobia inocula at low cost and inoculated seed should be acceptable to farmers.

Management factors affecting nitrogen fixation were discussed. Levels of weed control may be important to BNF and the speaker said survey data would be analyzed to determine effects of weeds. The effects of applied phosphatic fertilizers and micronutrients are to be investigated. BNF may be studied in low rainfall areas, in collaboration with FAO.

It was suggested that lines identified at CIAT with early nodulation and long duration of nodulation should be studied in Ethiopia.

Dry Bean Research and Production in the Eastern Semi-Arid Areas of Kenya

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Abstract

Dry bean (Phaseolus vulgaris L.) is a major food legume and source of income to farmers in the eastern semi-arid areas of Kenya. These areas are characterized by a low bimodal rainfall (500-700 mm), which is erratic and received usually in the first four to six weeks of each season. Dry bean is mainly grown in association with maize. However, associations with other crops such as sorghum, vegetables and young fruit trees are found.

Early maturing and heat tolerant cultivars have been developed for cultivation in these areas. These cultivars mature within 60-65 days of planting and yield an average of 1500 kg/ha in pure stand although higher yields may be attained with recommended agronomic practices. Their performance in drought, disease and insect pest stress conditions, impact, production constraints and research activities are discussed.

Introduction

Kenya is primarily an agricultural country, the industry supporting the smallholder low-income rural farmers who represent over 80% of the country's population. Dry bean (*Phaseolus vulgaris* L.) is the most important food crop after maize (*Zea mays* L.) in Kenya and grown usually in association with maize and other crops. The majority of Eastern Province lies in semi-arid zones V and VI, which are the main producing areas of dry bean. The province alone accounts for 35% of the country's total production with an average yield of 735 kg/ha (Kangethe and Ngalyuka, 1989). The national average yield is 700 kg/ha. Dry bean suffers from water stress at all stages of growth. Stress at flowering and pod filling coupled with high ambient temperatures causes flower drop and pod abscission and hence losses in yield.

Dry bean is grown in most parts of Kenya. However, the crop is usually not grown under 600 masl where temperatures are too high for good setting of pods under rainfed conditions (Stoetzer, 1983)

The climate of Kenya is diverse, ranging from cool wet highlands to hot arid low and medium altitude areas. These areas are conveniently grouped into six main agroecological zones, I to VI, based on rainfall, altitude and temperature (Jaetzold and Schmidt, 1983). With the rapid increase in population, farmers are increasingly moving into arid and semi-arid zones V and VI, which occupy 85% of the total land mass.

Production

In eastern semi-arid areas, dry bean is produced on small farms often in association with other crops such as maize, sorghum, young fruit trees and vegetables. A survey by Njuguna *et al.* (1981) between 1974 and 1975 indicated that in Kenya, 94% of the area planted with bean was in association and only 6% was in pure stand. Kenya is the largest single producer of bean in eastern Africa (Schwartz and Pastor-Corrales, 1989). Eastern Province alone produces over 130,000 metric tons per season (Kangethe and Ngalyuka, 1989), which constitutes 35% of Kenya's total production. Inputs such as fertilizer, chemicals, insecticides and fungicides are rarely used in bean production. Due to seasonal rotation and intercropping with maize, which is often fertilized either with farmyard manure or inorganic fertilizers, bean benefits indirectly.

Beans are produced both for home consumption and to earn income. The major cultivars grown are the local landraces, Mwezi Mmoja, Mwitemania and Katumani Bean 1, Katumani Bean 2 and Katumani Bean 9, pre-released cultivars (Rono, 1988) and Rose Coco in wetter, higher altitude areas (Ministry of Agriculture, 1988). Seed colour preferences are usually determined by market requirements. A notable increase in the cultivation of Rose Coco in semi-arid areas has been observed. This is due to the attractive market prices associated with the seed colour both locally and with the National Cereals and Produce Board (NCPB).

Production Constraints

The rainfall pattern is very erratic with extreme variation in both the monthly and annual amounts of rainfall. The times of beginning of both the "long" and "short" rains are very variable, making it difficult to determine planting dates when one can be assured of sufficient moisture for germination and crop growth. However, Bakhtri *et al.* (1982) and Itulya (1985) suggested that the best time to sow dry bean seeds in semi-arid areas is before the expected onset of rains.

There is a wide gap between the yields observed in experimental plots and those in farmers' fields (Table 1). The major constraints are unavailability of improved, good quality seed, diseases and insect pests, lack of inputs, poor soil fertility and drought stress. These factors, usually in combination, reduce yields. Disease and insect pest incidence and severity vary greatly depending on prevailing weather conditions and among seasons, years and locations (Stoetzer, 1983). The common diseases of semi arid areas are anthracnose, common bacterial blight, scab, rust, charcoal rot (ashy stem blight), bean common mosaic virus (BCMV) and root and stem rots (Smit, 1983). The main insect pests of bean in the semi-arid areas are the pod-borer (*Maruca testulalis*), pod-sucking bugs, beanflies and bean bruchids.

Dry bean does not nodulate well with native rhizobia, so nodulation is poor. Released cultivars have been shown to respond to nitrogenous and phosphatic fertilizer application (Grain Legumes Project, 1986).

Farmers often use seed preserved from the previous harvest or from their neighbours for cultivation in the next season. Seed may also be obtained from the market. Commercial seed companies supply limited quantities of certified

Table 1. Mean Yields (kg/ha) of Maize and Grain Legumes in On-Farm Trials in Matiliku Cluster, Machakos District from 1986 to 1988.

	Season[a]		
Crop	1986	1987	1988
Maize	1145[b]	844	2673
Bean	410	468	330
Pigeonpea	289	350	398
Cowpea	367	252	117

[a] Means of two seasons
[b] Means of six farmers

seed. However, most of their cultivars are suitable only for cultivation in high potential, high rainfall areas. Little certified seed of cultivars such as GLP 1004 is available. Due to limited sales, there is also a tendency by seed retailers to carry forward seed through several seasons, resulting in poor seed quality and hence low yields due to poor germination.

Most seed companies have little interest in multiplying bean seed cultivars suitable for cultivation in semi-arid areas due to low sales and hence low profits, associated with high risks and uncertainty due to climatic conditions. The most effective means of availing superior seed varieties of high quality to the farmers has been through non-governmental organisations (NGOs) and projects such as Machakos Integrated Development Project (MIDP) and Embu-Meru-Isiolo Projects (EMI). Limited amounts of seed have also been distributed by Laikipia Rural Development Project (LRDP)

Utilization

In eastern Africa, bean is mainly consumed in dry and green forms, together with young tender leaves. In Eastern Province, bean is consumed predominantly in the dry form, with the green form in small quantities. Tender bean leaves are rarely consumed.

Bean grains and maize are mixed together to cook *githeri* or dehulled maize may be mixed with beans to cook *muthokoi*. Boiled beans may be fried alone or with meat or with green vegetables and eaten as a relish with *ugali*, *chapati* or rice. Pre-soaking of beans before cooking is rarely practised in eastern semi-arid areas. Beans are also canned, mainly for sale in urban areas and for export.

Research Achievements

Research in dry bean has been in progress for several years in Kenya. Research was initially mainly conducted at the National Horticultural Research Centre (NHRC), Thika and the University of Nairobi. Dry bean research for areas 1,300 masl and below, with high temperatures, was initiated by the National Dryland Farming Research Centre (NDFRC) at Katumani in 1979. The main objectives were to develop high yielding, drought and heat tolerant, early maturing cultivars which are resistant to major diseases and insect pests, having acceptable organoleptic qualities and plant types.

The NHRC developed and released GLP 1004, a mwezi moja bean type and Mwitemania. These cultivars flower within 30-34 days and yield 1-1.5 tons/ha in pure stand. GLP 1004 is suitable for cultivation in cooler semi-arid areas. At NDFRC-Katumani, three determinate cultivars have been developed and pre-released to farmers (Rono, 1988). These cultivars are Katumani Bean 1 (Kat B1), Katumani Bean 2 (Kat B2) and Katumani Bean 9 (Kat B9). Kat B1 has a yellowish-green seed, whereas the seed of Kat B2 is cream. These cultivars are resistant to rust and BCMV and have some tolerance to angular leaf spot and charcoal rot. Yields also vary from 1-1.5 t/ha in pure stand. However, yields of over 2.0 t/ha may be obtained using recommended agronomic practices. Kat B9 has red seeds and is suitable for cultivation in altitudes 1,000 masl and below. It is heat tolerant. The three cultivars are medium to large seeded and flower in 30-34 days.

Although line-sprinkler irrigation is promising commercially, it is not reliable for screening lines for drought and heat tolerance (Masumba, 1984). Screening under field stress conditions and making selections based on seed yields (Singh and Mukunya, 1987) appears effective, especially where expensive equipment is not available.

Tepary bean (*P. acutifolius*) has been introduced for cultivation in semi-arid areas but was rejected in eastern semi-arid areas due to small seed size, taste and difficulty in cooking. However, some lines have been released to farmers in semi-arid areas, such as Turkana and West Pokot Districts, where bean was not cultivated previously.

Interspecific hybridization between dry bean and tepary bean has been attempted, to obtain drought and heat tolerant lines, but promising lines have not been obtained due to segregation of the hybrids back to their original parents. However, the dry bean hybridization programme at NDFRC-Katumani has identified high yielding mwezi moja and rose coco bean types similar in maturity to commercial types. In addition, an extra-early determinate mwitemania (Pinto bean) type has been identified, suitable for cultivation in lower altitude, lower rainfall areas. Although such a variety has critical source limitations (White and Izquierdo, 1989), modifications of planting pattern and density may enhance rate of crop cover and improve yields.

On-Farm Trials

Among the pulses in on-farm trials, bean produced better yields than cowpea and pigeonpea (Table 1). Improved cultivars and recommended agronomic practices were used. A survey from 1986 to 1988 showed that maize/bean was the most common association, practised by 41.3% of the surveyed farmers (Table 2). Dry bean was not observed in pure stand. The most common row arrangements are 1:1, 1:2 and 2:2 for maize/bean associations, the most popular being 1:2 - adopted by 25% of the surveyed farmers. Other common row arrangements are 1:1:1 and 1:2:2 for maize/bean/cowpea and 1:2:1 and 2:2:1 for maize/bean/pigeonpea associations.

Table 2. Percentages of Different Crop Combinations with Maize in Matiliku Cluster, Machakos District for Five Seasons from 1986 to 1988.

Crop association	Percentage of farms
Maize/bean	41.3
Maize/cowpea	11.2
Maize/pigeonpea	10.0
Maize/greengram	2.5
Maize/bean/pigeonpea	12.5
Maize/bean/cowpea	7.6
Maize/cowpea/pigeonpea	6.3
Others	8.6

A row arrangement of 1:1 maize/bean and 1:2:1 maize/bean/pigeonpea associations gave land equivalent ratios (LER) of 1.3 and 2.3, respectively. A 1:1 row arrangement at 45 or 60 cm row width is more suitable during seasons of lower rainfall whereas a 2:2 arrangement of similar row width is suitable during seasons with favourable rainfall (Thairu and Ariithi, 1988). Farmers with larger farms (10 ha and above) obtain better yields per hectare than farmers having smaller farms. This trend is probably due to purchase by larger farmers of modern yield-increasing inputs such as chemical fertilizers and better agronomic management.

Conclusions

Dry bean is a major source of protein and income for farmers of the eastern semi-arid areas of Kenya. Eastern Province is the leading producer and accounts for 35% of the country's total production. Large and medium seeded varieties; and rose coco, mwezi moja, pinto and red seeded types are most preferred. Types with yellowish-green and cream seeds are also acceptable to limited consumers.

Drought stress, weeds, the diseases - anthracnose, charcoal rot and common bacterial blight - the insects - beanflies, podborers, pod sucking bugs in the field and bean bruchids in stores - are important factors limiting yields. Unavailability of good quality seed of improved cultivars and of modern yield increasing technologies also contributes to poor yields. There is need to develop promiscuous nodulating lines, which are early in nodulation and have a prolonged period of N-fixation.

Maize/bean is the most preferred crop association. In lower altitude, hotter areas, sorghum/greengram is common. A 1:2 row arrangement of maize/bean is most preferred by farmers, although 1:1 gives a high LER (1.3). A row arrangement of 1:2:1 maize/bean/pigeonpea is also common. More research should be done on 1:1, 1:2 row arrangements for maize/bean and 1:2:1 arrangements for maize/bean/pigeonpea in association. In addition, breeding for resistance to the major diseases and insect pests is expected to contribute much to increasing bean production in Kenya.

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Possible Genetic Solutions to Bean (Phaseolus vulgaris L.) Production Constraints in Western Kenya

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Abstract

Western Kenya (Bungoma, Busia and Kakamega Districts of Western Province and Nandi and Siaya Districts of Nyanza Province) covers an area of more than 13 thousand km² with a population of nearly 3 million. It has high potential for agriculture and is one of the major bean producing areas of Kenya. The climate is mainly humid, sub-humid and semi-humid but the soils (Nitosols, Acrisols, Vertisols, Luvisols and Ferralsols) are relatively infertile. The agriculture is at subsistence levels, producing maize, bean, banana, sweet potato and local vegetables, with some sorghum, finger millet, groundnut, sugar cane, fruit trees, coffee and tea. Bean is found in pure stand or in association with other crops, mainly maize but also with sorghum, cassava, cotton, sugar cane, coffee or banana. The main constraints to bean production include diseases, insects, poor soil fertility, excessive and inadequate rainfall, inappropriate cultivars and labour shortage. Breeding offers the most appropriate solution to these constraints and the improvement of bean production in western Kenya.

Introduction

Nyanza and Western Provinces together form western Kenya, situated between 34^{o}-35^{o}E and 1^{o}N-1^{o}S. The Western Agricultural Research Centre (altitude, 1,585 masl; average annual rainfall, 1,935 mm; average mean temperature 20.6^{o}C) caters for Western Province and Siaya and Nandi Districts in all agricultural activities covering an area of 13,462 km^2 with a population of about 3 million people (Table 1). The region has high potential for agriculture and is one of the major bean growing areas of Kenya (Table 2) (Figure 1).

Physical Environment

Topography

Most land to the east, in Kakamega, Bungoma and Nandi, consists of uniform undulating uplands with a succession of valleys and highland areas. In Busia and Siaya, the land is mainly plains which slope very gently westwards to Lake Victoria.

Climate

Most of the area is covered by humid, sub-humid and semi-humid zones (Tables 3 and 4, Figure 2). The rainfall is more or less continuous with

Figure 1. The Geographical Distribution of the Main Bean Growing Districts in Kenya.

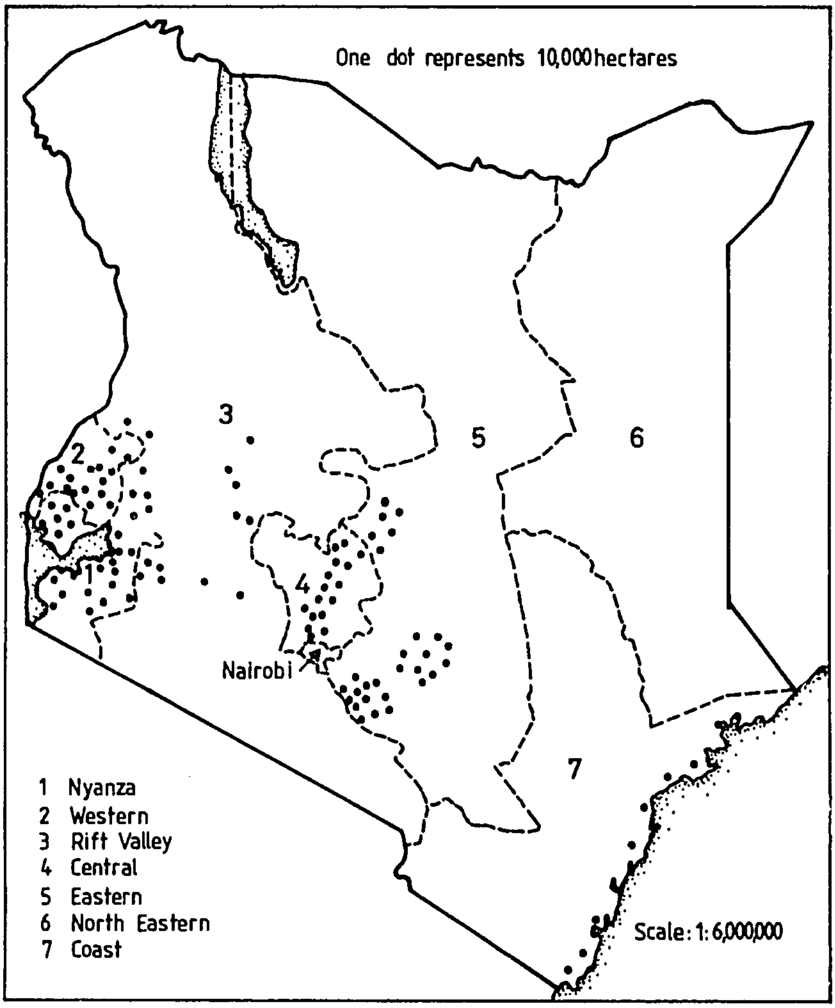


Table 1. Area, Population and Density by District of Mandate Area of Western Agricultural Research Centre, 1979.

District	Total land area (km^2)	Agricultural land area (km^2)	Population ('000s)	Population density (km^2)	Agricultural land (ha/person)
Bungoma	3,074	1,992	500.4	163	0.40
Busia	1,626	1,349	300.0	185	0.45
Kakamega	3,495	2,548	1,300.0	372	0.20
Nandi	2,745	1,926	300.0	109	0.64
Siaya	2,522	2,059	474.0	188	0.43
Total	13,462	9,874	2,874.4	214	0.34

Source: Anon. (no date)

Table 2. Area Production and Yield of Bean in Kenya by Province.

Province	Area (ha)	Production (tons)	Yield (kg/ha)
Central	86,166	54,184	629
Eastern	178,896	131,545	735
Western	90,106	50,639	562
Rift Valley	120,782	89,191	738
Nyanza	61,065	50,816	832
Coast	3,412	2,158	632
Total	540,533	378,533	701

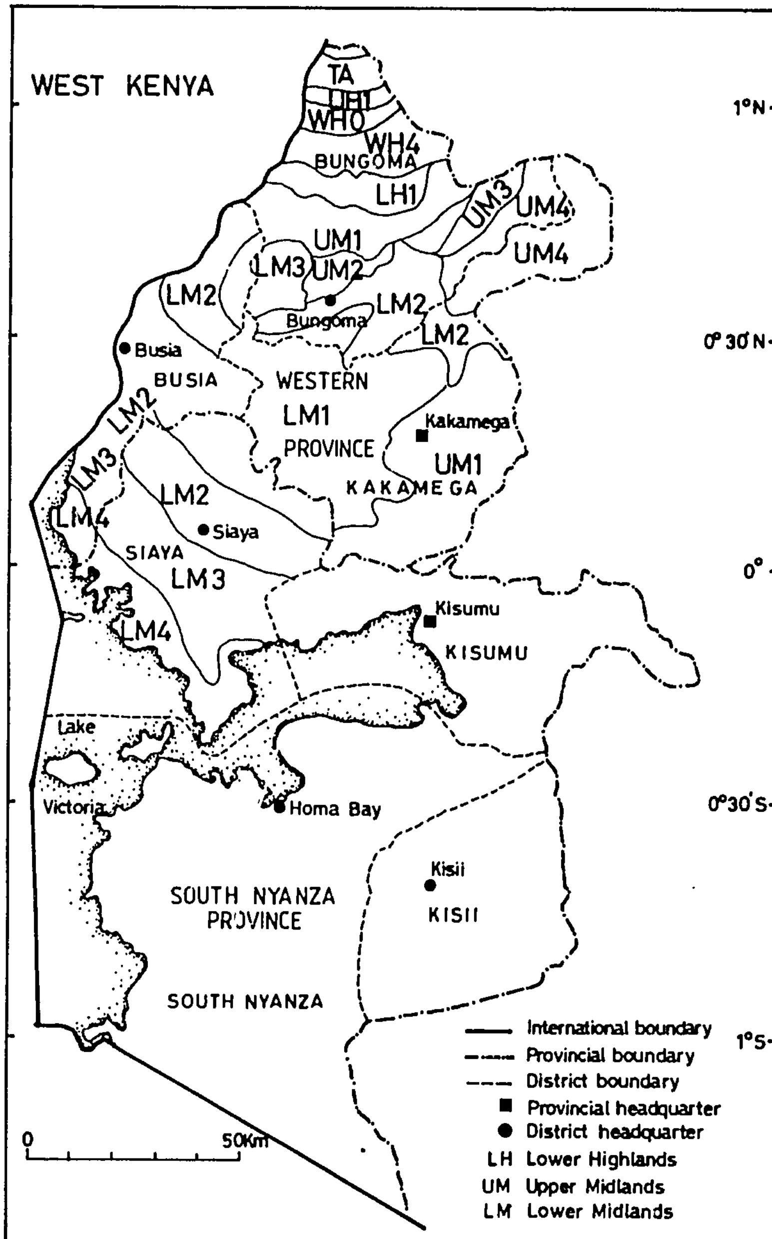
Source: Anon. (1989a)

little distinction between the first and the second rains due to the daily westerly winds from Lake Victoria which converge with south-easterly trade winds. This causes air to rise and produce heavy showers, especially in the afternoons, resulting in relatively wet agro-ecological zones. The average annual rainfall in Bungoma District ranges from 1,000 to 1,800 mm with annual mean temperatures of 21-22°C. Kakamega and Nandi Districts receive annual rainfalls of between 1,000 and 2,200 mm with annual mean temperatures from 18 to 20°C and 8 to 26°C, respectively. In Siaya and Busia Districts, the average annual rainfall is around 1,000 mm, accompanied by relatively high humidity due to the proximity of Lake Victoria.

Soils

The dominant soils in western Kenya include, Nitosols, Acrisols and Vertisols, in addition to Luvisols and Ferralsols in Siaya and Busia

Figure 2. Agroecological Zones of Western and Nyanza Provinces of Kenya.



Districts. They are generally not fertile because they contain little recent volcanic or other young nutrient-rich parent material. It is established that they are rich in potassium (though this has been depleted to deficient levels by continuous cropping in many situations) and vary greatly in nitrogen and phosphorus contents (Table 5). In the tea zone, the soils are moderately acidic which results in apparent calcium deficiency. Because of these problems, manure and fertilizer are needed to improve agricultural productivity.

Table 3. Classification of Agricultural Land (km^2) in Western Province, Siaya and Nandi Districts according to climate.

District	Total land area	Agricultural land			
		Humid and sub-humid	Semi-humid transitional	Semi-arid	Total
Bungoma	3,074	1,210	782	0	1,992
Kakamega	3,495	1,918	630	0	2,548
Busia	1,626	927	422	0	1,349
Siaya	2,522	985	1,054	20	2,059
Nandi	2,745	1,136	790	0	1,926

Source: Jaetzold and Schmidt (1982a)

Table 4. Main Agro-Ecological Zones of Western Kenya

Zone[a]	Potential major crop	% of total
Upper highlands (UH)	pyrethrum	0.37
Lower highlands (LH)	tea	11.57
UM_1/UM_2	coffee	13.47
UM_3/UM_4	maize/sunflower	15.10
LM_1/LM_2	sugar cane	41.29
LM_3/LM_4	cotton	18.16

UM = upper midlands; LM = lower midlands
Source: Jaetzold and Schmidt (1982b)

Farming Systems in Western Kenya

The majority of farmers practice subsistence farming with average agricultural land per household of 0.56 ha. Nearly all farmers grow maize, bean, banana, sweet potato and local vegetables. Other crops include sorghum, finger millet, groundnut, sugar cane, fruit trees, coffee and tea. Most farmers also keep livestock. All farmers grow maize and beans in association (mixed cultivars). There are cases of maize and bean in association with coffee, sorghum or cassava. Maize is planted in rows and bean in between the rows, at the onset of rains. Table 6 shows the area and production of major crops in Bungoma District.

Table 5. Soil Analysis for Farms in Kakamega District.

	Arable farm			Tea plantation (clays)		
Soil characteristic	No. of samples	Mean	S.E.±	No. of samples	Mean	S.E.±
pH	8	5.30	0.130	8	4.94	0.046
Sodium[a]	8	0.140	0.040	8	0.088	0.027
Potassium	8	0.115[b]	0.026	8	0.075[b]	0.015
Calcium	8	1.08[b]	0.383	8	0.425[b]	0.045
Magnesium	8	1.03[c]	0.165	1	Trace	NA
Manganese	8	0.657	0.052	8	0.534	0.038
Phosphorus (ppm)	8	8.00[b]	0.926	8	6.75[b]	0.648
Organic carbon (%)	4	1.13[b]	0.119	4	1.06[b]	0.078
Hp	6	1.62[d]	0.210	8	2.15[d]	0.107

[a] expressed in meq/100 g soil, where other units not shown;
[b] half or more of the samples were at levels considered critically deficient;
[c] four of the samples had trace quantities only;
[d] all samples at levels considered to be toxic
Source: Anon. (1989b)

Table 6. Areas Harvested and Production of Major Crops in Bungoma District.

Crop	Area harvested ('000 ha)	Production ('000 t)
Maize	78.00	141.84
Bean	31.00	16.99
Sorghum	1.50	0.99
Finger Millet	41.19	2.26
Cassava	1.60	23.20
Sweet potato	1.90	26.60
Coffee	4.05	1.07
Cotton	4.96	0.15
Sunflower	9.04	0.14
Sugar cane	292.00	43.40

Source: Anon. (1985)

Bean Production and Its Constraints

Production Systems

Western Kenya is a major bean growing area of Kenya (Table 7). An old-established system of production is intercropping bean with maize. Other intercrops include bean with sorghum, cassava, cotton and sugar cane. There are areas where maize and bean are grown in association with coffee or banana.

Diseases

In the National Bean Performance Trials conducted in the region, angular leaf spot, anthracnose, scab, floury leaf spot, rust, bean common mosaic virus and ascochyta blight are all recorded. Reports indicate that diseases are the chief limiting factors to bean production in western Kenya, aggravated by constantly warm temperatures and moist conditions.

Table 7. Area, Production and Yield of Bean in Western Kenya by District.

District	Area (ha)	Production (t)	Yield (kg/ha)
Kakamega	41,310	33,048	800
Bungoma	31,353	14,211	543
Busia	11,967	6,939	580
Siaya	17,526	8,763	500
Nandi	5,357	4,919	918
Total	107,513	67,880	668

Source: Anon. (1989a)

Insects

Bean is grown continuously cropped and in association, which encourage the build-up of pest populations. The major insect pests of western Kenya are: beanfly (*Ophiomyia phaseoli*), thrips (*Megalurothrips sjostedii*), aphids (*Aphis spp.*) and bean weevil (*Acanthoscelides obtectus*)

Insects damage the crop through defoliation, stem attack, eating leaves and pods, sucking juice from young growing points and spread of diseases.

Low Soil Fertility

Most soils in western Kenya are poor in phosphorous and nitrogen statuses. Because of these problems, large amounts of manure and fertilizer are needed for improved bean production.

Climate

Excessive rainfall often causes poor germination and severe disease incidence in Kakamega, Bungoma and Nandi Districts. In Siaya and Busia Districts stress due to low moisture can occur. Too warm temperatures cause flower abortion in Siaya and Busia Districts.

Cultivars

There are several local landraces and improved cultivars grown. The local landraces are susceptible to common bean diseases, for example anthracnose, angular leaf spot, rust, halo blight and BCMV.

Improved cultivars of determinate growth habit include: GLP 2 (Rose Coco type seed); GLP 24 (Canadian Wonder); GLP 585 (Red Haricot); GLP 1004 (Mwezi Moja); GLPX 92 (Pinto - Mwitemania); and GLPX 1127A (New Mwezi Moja). GLP 2 has medium to good yield and matures early but has poor pod clearance. It shows early resistance to angular leaf spot and mild resistance to BCMV and rust. GLP 24 is poor yielding and late maturing with very poor pod clearance but with some resistance to angular leaf spot, BCMV and rust.

Bean cultivars with resistance to diseases and adapted to cultivation in association with maize are lacking.

Socio-economic Aspects

Labour shortages are considered to seriously constrain bean production.

The Challenge and Solutions

The challenge in western Kenya is to devise means of achieving significant improvement in productivity of bean without heavy reliance on added inputs and without adversely disrupting existing cropping systems. Diseases are the most important constraints to bean production in western Kenya, followed by insect pests (particularly beanflies), poor soil fertility, lack of suitable varieties for intercropping and drought.

Fortunately all these constraints lend themselves to genetic solutions. The first gift agricultural science can offer a crop producer is a range of improved cultivars that are adapted to local environments and have built-in resistance to as many important disease and pests as possible. Most diseases can only be controlled by genetic resistance. Resistant varieties cost farmers nothing nor does their adoption necessarily disrupt farming systems. As such, genetic solutions - screening, selection and breeding - to the above constraints are of utmost importance for the improvement of bean production in western Kenya, through the following strategies.

Expansion and Evaluation of Germplasm

The objective is to increase germplasm collection of bean to to identify suitable new cultivars.

Breeding for Resistance to Major Bean Diseases

This would focus on angular leaf spot, anthracnose, rust, BCMV and halo blight and is achievable through: transferring single genes such as the "Are" gene for anthracnose resistance and other resistance genes to popular (common) bean types of the region; transfer and incorporation of characters like halo blight resistance by pedigree breeding, where complications exist due to the number of strains of different pathogenic character.

Screening for Insect Resistance

In particular for beanflies. The objective would be to identify germplasm resistant to beanfly attack through screening available germplasm.

Screening for Low Phosphorous Tolerance

To identify suitable cultivars for the low soil fertility areas in the region. The objective would be identify genotypes that efficiently use minimal amounts of phosphorous from the soil.

Screening for Nitrogen Fixation

There is strong evidence of major differences among bean genotypes in ability to fix nitrogen. Climbing and strongly indeterminate cultivars are consistently superior to those of most bush cultivars. There is good potential for climbing bean in Kakamega, Bungoma and Nandi Districts due to high available moisture and predominately intercropping systems. Modest estimates from Kabate put nitrogen fixation at 55 kg/ha.

It is estimated (CIAT, 1987) that a seed yield of 2,000 kg/ha requires the accumulation of 80-110 kg/ha N in the plant and seed. This shows potential for N-fixation to increase the yields of bean in Kenya considerably.

Selection and Breeding to Combine Other Important Characteristics

These include: pod clearance; suitability for mixed cropping; ecological adaptability; and drought resistance.

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Common Bean (Phaseolus vulgaris) Production and Research in the Sudan

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Abstract

In the Sudan, common bean is the second most important food legume. It is cultivated on an area of about 23 thousand hectares. Most of this area is in the south. Here, yields average about 400 kg/ha, while in the north, where the crop is irrigated, the average yields are about 1,300 kg/ha. Bean research has been conducted since 1960, mainly at Hudeiba Research Station, in northern Sudan. Important production constraints at which research has been directed include: poor yields; soils problems, such as salinity and sodicity; insect pests, especially whitefly; and diseases, especially curly top virus. Genotypes have been selected that are tolerant to some of these hazards. Whitefly has been successfully controlled by chemicals. Selection for improved nitrogen fixation is in progress.

Importance of Common Bean in the Sudan

Common bean (*Phaseolus vulgaris*) is one of several food legumes that have been cultivated in the Sudan for many years. The list of legumes includes faba bean, chickpea, dry pea, cowpea, lentil, pigeon pea, lupin, hyacinth bean and fenugreek. The area under bean in the Sudan is estimated to be about 23 thousand ha, most of which is in the south. Only 3 to 4 thousand ha are grown in the north. There is little information on production practices in the south, so the work reported here applies mainly to northern Sudan.

The cultivated area in northern Sudan was in excess of 7 thousand ha in the sixties but has since declined due to the following reasons:

a) competition from other legume crops, especially faba bean, whose area has more than doubled during the past two decades;

b) common bean is grown on privately-owned smallholdings and due to shortage of fuel supply and consequently irrigation water, farmers tend to grow perennial crops that suffer less from water shortage; and,

c) bean suffers from many environmental hazards especially soil salinity, which makes extension of the crop to areas distant from the Nile or to newly reclaimed areas difficult, since their soils usually contain large amounts of salts.

Crop Husbandry

In the north, common bean is grown as an irrigated crop. It is found to be best suited to the rich alluvial soils near the river (*geref* land) or to the basins that are formed by the receding water of the Nile. These soils are generally very fertile and their salt content is low, so they produce moderately high yields.

In areas subject to flooding by the Nile, bean is grown with minimum tillage operations, the seeds being sown by means of a digging-stick. In areas distant from the Nile, soils are usually prepared by animals or tractors. Usually neither fertilizers nor chemicals to control pests or diseases are applied and the crop receives 4 to 6 irrigations.

In the north, bean is cultivated in monoculture as a winter crop, sown usually in late October or early November. The crop is harvested after about 90 days. Meteorological data from Hudeiba Research Station (elevation 350 masl), situated in the centre of the bean growing area, is presented in Table 1.

Table 1. Meteorological Data (Averages of Ten Years) for Hudeiba (17° 34'N, 13° 56'E)

Month	Mean temperature °C		R.H.% at 0600 hrs GMT	Evaporation[a] (Piche) mm/day
	Maximum	Minimum		
January	29.7	12.9	43	12.2
February	33.0	15.0	35	15.6
March	36.1	17.4	27	19.7
April	40.0	21.3	22	23.2
May	42.3	24.8	20	22.4
June	42.4	26.6	25	22.9
July	39.8	25.8	42	19.5
August	39.7	25.5	47	18.9
September	41.0	25.2	37	18.4
October	39.2	23.2	33	18.3
November	34.5	18.9	40	15.3
December	30.4	14.3	45	12.5

[a] averages of five years

Types Grown

The dominant cultivars are climbing with rectangular, white glossy seeds that measure 1-1.2 cm in length and weigh about 20-25 g per 100.

Constraints Limiting Production

The principal constraints to production of common bean are:

1. Poor cultural practices - late sowing, infrequent irrigation and lack of fertilization.

2. Competition with other, higher-value crops.

3. Biotic constraints, including white fly (*Bemisia tabaci*), which is believed to transmit viral diseases.

4. Soil salinity - in areas distant from the Nile.

5. Lack of certified seeds and modern seed cleaning equipment.

Bean Research Programme

Research on bean has been conducted at Hudeiba Research Station since its establishment in the early 1960s, but has now been extended to other stations.

Breeding and Cultivar Improvement

The main objectives have been to:

- breed for high yield potential and yield stability,

- screen for tolerance to curly top disease, and

- screen for tolerance to sodium toxicity.

Seed Yield

Introductions from the United States, CIAT and African countries and collections made in different parts of the Sudan have been evaluated. Introduced materials except for some Great Northern American cultivars, which yielded similarly to local cultivars, have proved ill-adapted. The programme has concentrated mainly on screening local materials, which has the disadvantage of reliance on a narrow genetic base. However, a cultivar called Ro/2/1, a good yielding line, moderately tolerant to sodium toxicity has been released and another, HRS 545, which is also good yielding, tolerant to sodium injury and with good yield stability over years and localities, is a candidate for release.

Curly Top Disease

Curly top disease is caused by a virus thought to be transmitted by the whitefly (*B. tabaci*). Vetten (personal communication) was able to isolate cowpea mild mottle virus (CMMV) from all bean samples from Sudan suggesting that this virus, which is transmitted by the whitefly, is the causal agent of the disease.

A programme of selection for resistance was started in local materials in 1969 (Yassin, 1970-73), but nothing with worthwhile resistance was identified. Reliance on natural infection may account for the lack of conclusive results.

Tolerance to Sodium Toxicity

Genotypic differences in susceptibility to sodium toxicity were reported by Ayoub (1974). Snap bean lines were more susceptible than the dry beans, Pinto and Red Mexican (Table 2).

Soil amendment is another approach to sodium toxicity. Ayoub (1975) found that gypsum and wheat straw mulch reduced the translocation of sodium from roots to stems and leaves under high external sodium levels and thus could be used to ameliorate the condition.

Table 2. Survival of Bean Cultivars in a Sodic Soil (Ayoub, 1974).

Cultivar	Mortality %
Top Crop	99.1
Contender	97.8
Extender	96.8
Tender Green	96.2
Tender Crop	90.8
Ro/2/1	52.8
Red Mexican	22.1
Pinto	21.1

Agronomic Research

Trials to identify improved agronomic practices have been conducted since 1961. It is now established that the best yields are obtained by sowing during the last two weeks of October. Bean produced better yields on ridges 60 cm wide than on 120 cm beds and at spacings of 60 x 20 cm or 60 x 10 cm than at wider spacing. Current practice is to sow seeds at 60 x 20 cm apart with two seeds/hole on both sides of 60 cm ridges. Irrigation at 7 or 10 day intervals gives the best bean yield (Taha, 1982).

Control of Pests, Diseases and Weeds

Pests

Bean is attacked from growth to harvest by a number of insects and vertebrate pests (Table 3). The most important of these is the whitefly. Besides direct damage, this pest also transmits virus diseases. In years of heavy infestation the pest completely devastates the crop. Other pests seldom reach a level which necessitates control. Of these, the most important is *Aphis craccivora*, which attacks the crop late in the season. Early sown crops usually escape damage.

Bean seeds can be stored for years without danger from storage pests. The most important storage pests in northern Sudan are *Bruchidius incarnatus* and *Trogoderma granarium*. *B. incarnatus* lays eggs on the seeds but the young

Table 3. Pests of *P. vulgaris* in Northern Sudan

Common name	Latin name
Red melon beetle	*Aulacephora africana* (Weiss)*
Cowpea aphid	*Aphis craccivora* (Koch.)
Whitefly	*Bemisia tabaci* (Genn.)
Thrips	*Caliothrips impurus* (PR)
Thrips	*Caliothrips sudanensis* (Bagn & Cam)
Thrips	*Frankliniella schultzi* (Tryb)
Jassids	*Erythroneura lubiae* (china)
Pod borers	*Heliothis armigera* (HB)
Slugs	*Limicolaria kambeul* (Brug)*
Flea beetles	*Podagrica puncticollis* (Weise)
Lygus bug	*Taylorilygus vosseleri* (Popp)
Spider mites	*Tetranychus telarius* (h.)
Spider mites	*Tetranychus sinnabrinus* (Boisd)
Wild rabbits	undetermined species
Nile rat	*Arvicanthus niloticus*
House sparrows	undetermined

* recorded from southern Sudan.

larvae die immediately after penetrating the seed coat. Though the exact mechanism of resistance has not been determined it is possibly an antibiosis reaction. *T. granarium* is found as a secondary pest on seeds previously damaged by *Heliothis armigera*.

Research on the problem of whitefly was directed at assessment of their economic importance and screening insecticides. Infestation reduced seed yields by almost 80% in some years. Of the many insecticides tested since 1984, the most promising are Temik (aldicarb), carbofuran and Sumicidin (fenvalerate) (Table 4).

Diseases

Three diseases are known to infect bean in northern Sudan. These are: curly top, seedling blight and mosaic.

Curly top, as indicated above, is probably caused by the cowpea mild mottle virus. The incidence of the disease is influenced by sowing date. Ali *et al.* (1988) reported that curly top incidence was significantly more in bean sown on 1 October than at other times (Table 5).

The seedling blight (*Macrophomina phaseolina*) occurs early in the season, causing seedling mortality. Its incidence is also influenced by sowing date - sowing in early October results in greater incidence than later sowings (Table 5) (Ali *et al.*, 1988). Seed dressing with Aldrex A, Benlate and Fernasan significantly reduced disease incidence on bean in pots (Ibrahim, 1973). In the field, Captan provided some protection (Freigon, 1976) but this requires confirmation.

Table 4. The Effects of Insocticides on Numbers of Whitefly/Leaf and Seed Yields (kg/ha) of Bean Cultivar Ro/2/1 at Hudeiba Research Station from 1984 to 1985.

	Seasons								
	1984/85		1985/86		1986/87		1987/88		
Insecticide	Yield	No.	Yield	No.	Yield	No.	Yield	No.	Mean yield
Temik	387	2.5	1159	9.8	1026	1.8	1486	8.8	1014
Carbofuran	190	13.9	1215	18.2	1078	2.4	1337	10.9	955
Sumicidin	NT	NT	1249	16.9	1041	3.0	1492	10.0	1261
Untreated	54	54.4	1076	29.9	639	4.2	860	22.9	671
S.E.±	32.8	3.8	58.5	4.2	54.9	0.89	68.2	1.71	

NT = not tested

Table 5. Effect of Sowing Date, Cultivar and Whitefly Control on the Incidence (percentages transformed to square root of x+1) of Dry Bean Diseases on Two Soil Types.

Treatment	Seedling blight		Curly top		Unidentified	
	Sandy clay	Clay	Sandy clay	Clay	Sandy clay	Clay
Sowing date						
10 Oct	3.09	2.57	3.28	2.13	6.13	5.01
20 Oct	1.13	1.38	2.73	2.00	1.87	1.59
09 Nov	1.10	1.01	2.55	1.83	1.12	1.00
29 Nov	1.00	1.00	2.37	2.60	1.00	1.01
S.E.±	0.17	0.10	0.18	0.12	0.27	0.18
Cultivar						
P_1	1.49	1.47	2.68	2.08	2.41	2.22
Ro/2/1	1.67	1.51	2.79	2.20	2.65	2.09
S.E.±	0.12	0.07	0.13	0.09	0.19	0.13
Whitefly control						
Sprayed	1.53	1.51	2.64	2.04	2.30	2.27
Unsprayed	1.64	1.47	2.83	2.24	2.76	2.04
S.E.±	0.12	0.07	0.13	0.09	0.19	0.13

Mosaic is believed to be caused by bean common mosaic virus but its incidence is generally low.

Weeds

Of the many herbicides tested over four seasons, Basagran resulted in the best bean yield and the least number of weeds per square meter, while treflan resulted in the poorest yield and weed control (Mohamed and Taha, 1983).

Nitrogen Fixation

Bean generally nodulates poorly in the Sudan. Nitrogen significantly increases bean yields (Abdel Gabar, 1970; 1971), but not phosphate. Habish and Ishag (1974) reported considerable response to inoculation with *Rhizobium*. Screening for more efficient strains is now in progress.

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Current Bean Research in Somalia

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Abstract

In Somalia, there are two main growing seasons, gu' and der, of which the former is longer and more reliable. Common bean is not widely grown but offers potential. Bush bean and empoasca resistant materials from CIAT are earlier and produce better yields than local cultivars but all are susceptible to fusarium wilt.

Introduction

In Somalia, there are two main growing seasons, *gu'* (April- June) and *der* (October-December). Monthly rainfall from several centres are shown in Table 1 and mean rainfall in Figure 1.

Although rainfall is irregularly distributed in both seasons, the *gu'* season is the longer and more reliable. Furthermore, the *gu'* rains are supplemented by coastal showers (*hagai*) occurring from the end of June to August up to 60 km from the coast. During the periods of the coastal showers, temperatures are cooler than in other months of the year (maximum 28°C and minimum 20°C). The *der* season is generally concentrated in the months of October to November. From November onwards hot dry weather prevails in the Shabelle, Jubba and Bay Regions.

Beans are not widely grown in Somalia, but are scattered in very isolated and negligible areas of the country. Common bean is grown to a small extent at Jilib in the Jubba Regions and parts of the Shabelle Regions. Some common bean is grown for green pods and lima bean for grain purposes by isolated farmers on the Shabelle and Jubba Rivers (Figure 2).

Bean is not a traditional crop, but has potential in Somalia. Observation nurseries are therefore planned to test its adaptability and to identify genotypes with resistance to pests and diseases of economic importance and that fit existing agricultural systems. Pulses will help solve daily problems of a large population migrating to the towns. Furthermore, pulses are the main source of protein for the poor and low income groups of urban and rural areas because of the high prices of animal products (meat, milk, cheese and eggs) increasing day by day in relation to inflation. There are no other alternatives for the poor man than use of the pulses available to the farming community. These problems have stimulated the initiation of bean research in Somalia.

Materials and Methods

Bean lines introduced from CIAT were tested at the Central Agricultural Research Station, Afgoi in the *der* (October-December) 1988 and *gu'* (April-June) 1989 seasons at elevations between zero and 200 masl.

Figure 1. Somali Democratic Republic, Regions and Districts.

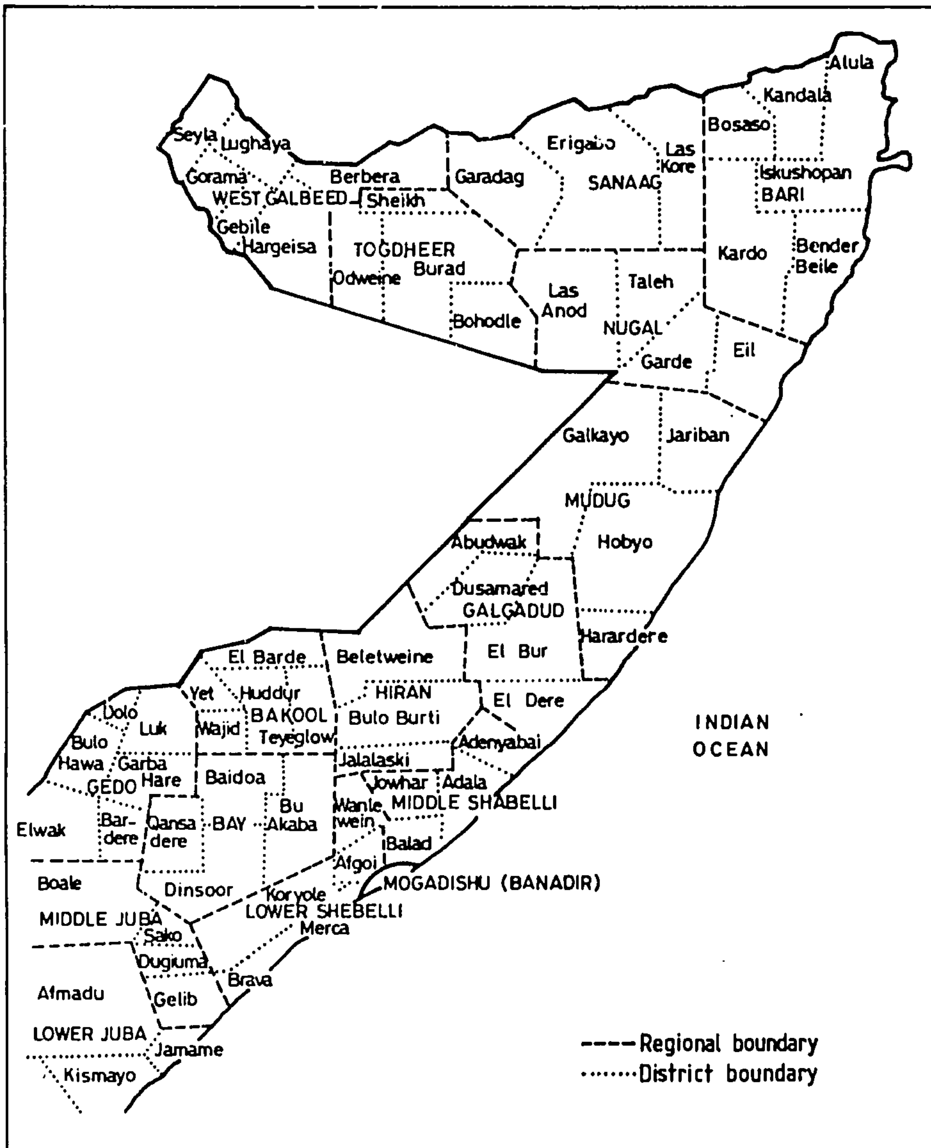

Figure 2. Monthly average rainfall for all Somalia.

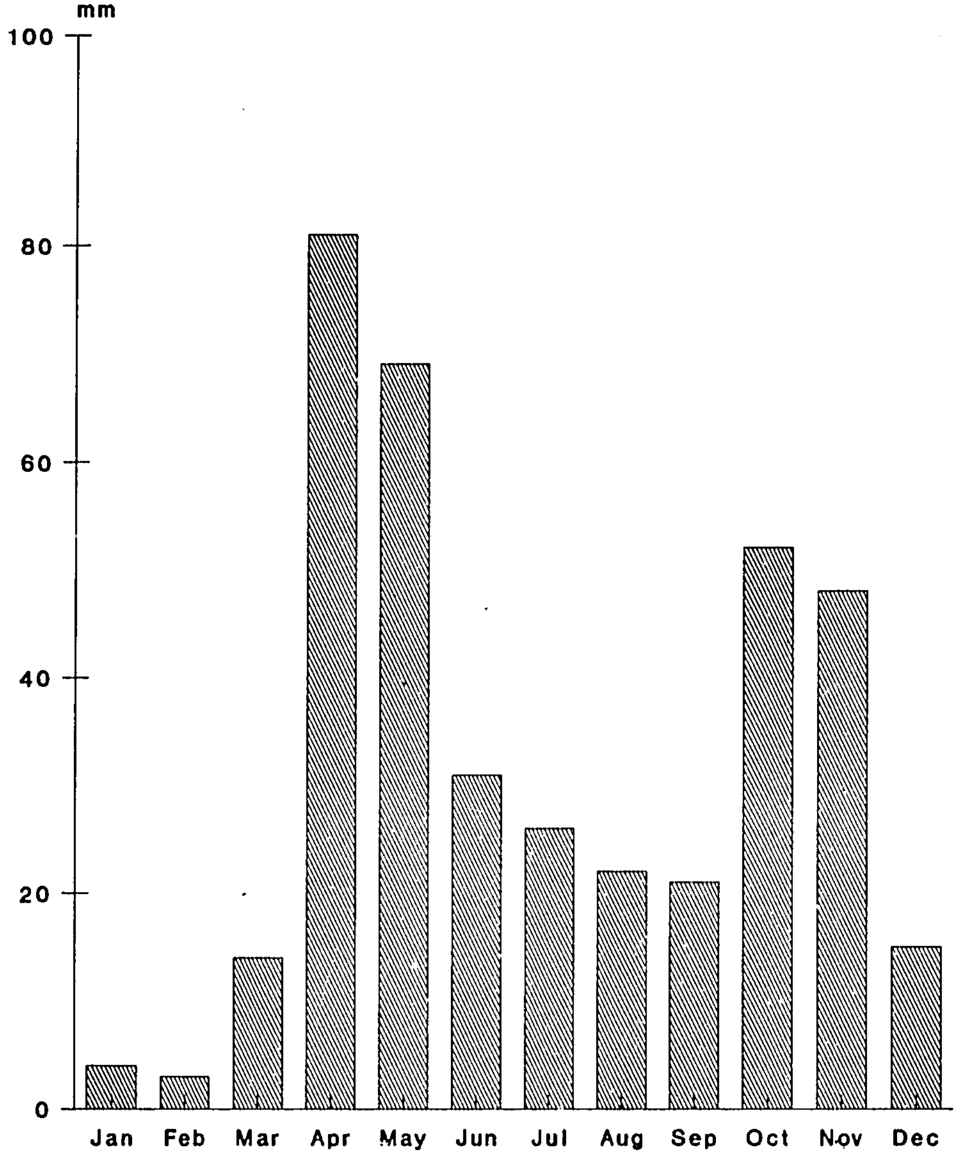

Table 1. Mean Monthly and Annual Rainfall (mm) at Selected Stations in Somalia (Means of at least 10 Years).

Station	Region	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Borans	Awdal	15	18	41	53	58	41	66	117	69	10	18	2	508
Bargeles	W-Galbeed	2	8	25	61	61	58	43	81	58	10	8	2	417
Burao	Togdheer	3	1	5	30	58	18	10	13	25	20	13	3	199
Erigavo	Sanaag	18	13	33	38	81	63	10	41	114	8	13	2	434
Gardo	Bari	0	0	7	23	30	4	1	3	6	18	4	3	99
Garowe	Mugaal	2	0	3	29	14	0	0	0	0	15	0	0	63
Galkayo	Mudug	0	1	2	26	57	3	0	1	2	45	19	1	157
Beledweyne	Hiraan	0	0	6	55	66	8	3	2	9	59	27	5	240
Jowhar	Middle Shabelle	5	1	22	94	87	24	26	16	12	104	84	21	496
Balad	Middle Shabelle	9	2	9	94	69	36	22	12	16	75	94	30	468
Mogadishu	Banaadir	0	0	8	58	62	88	84	42	23	33	41	8	447
Afgoi	Lower Shabelle	2	3	5	82	85	57	54	24	7	55	91	29	494
Wanlaweyn	Lower Shabelle	6	4	8	165	95	30	33	18	14	94	71	27	565
Janaale	Lower Shabelle	1	0	4	76	74	81	55	47	22	32	53	26	471
Sablaale	Lower Shabelle	4	0	0	94	108	40	32	8	8	14	65	27	400
Allessandra	Middle Juba	2	1	8	139	111	54	53	18	18	74	60	48	586
Bardheere	Gedo	5	5	20	93	56	13	20	5	6	65	68	28	384
Lugh Ganana	Gedo	2	4	28	113	40	1	3	0	1	47	55	15	309
Dinsoor	Bay	4	0	21	130	53	8	18	12	2	96	94	13	451
Baidoa	Bay	2	4	23	147	115	15	18	6	13	128	87	13	571
Kuddur	Bakool	2	1	11	108	69	2	5	1	9	100	50	4	362

Source: Anon. (1988)

The seed materials are categorized as follows:-

a. Bush Bean Nursery (256 entries).

b. Empoasca Resistance Nursery (20 entries)

The lines were sown in single rows 4 m long and 75 cm apart. Plant to plant spacing was 20 cm within rows, with one plant/hill. No fertilizer was applied, but other standard cultural operations were practised and the crops were irrigated.

Results

Bush Bean Nursery

From the 256 entries evaluated in *der* 1988, the 25 most promising were retested in *gu'* 1989 (Table 2).

The *der* season of 1989 was unfavorable for all crops because of unusually heavy rain which disturbed the effectiveness of the evaluation preventing some cultural operations.

The entries tested were similar in plant vigour and flowered from 26 to 30 days except the local check. All were susceptible to *Fusarium* spp. but there was little damage due to beanflies, flower thrips or common bacterial blight.

Table 2. Characteristics of Entries in Bush Bean Nursery at Afgoi in *Gu'* 1989.

CIAT entry nos.	Entry names	Harvest plant count	Vig-our	DFF	DM	Grain yield (kg/ha)	Disease and pest scores BF	FT	FW	CBB
15	ABA 20	38	5	27	70	313	3	4	8	3
27	ABA 37	30	5	30	75	352	4	3	8	2
43	ABA 64	46	7	30	77	380	3	3	8	3
81	Fleetwood	49	5	25	65	433	3	4	8	2
82	D 77196	49	5	32	67	315	3	3	8	3
93	BLM 83	59	7	32	67	320	3	2	9	2
95	D 158	24	7	39	77	361	3	2	8	3
105	RGR 14	37	5	49	74	352	3	3	8	2
147	WAF 55	32	6	27	64	378	3	2	8	3
154	WAF 63	12	5	30	67	400	2	3	8	2
157	WAF 67	34	5	30	67	738	2	2	7	2
158	WAF 69	37	5	32	74	300	2	3	8	3
165	WAF 77	19	6	39	79	320	3	2	8	2
166	WAF 78	17	5	28	67	302	3	2	8	3
179	WAF 91	42	5	25	72	385	2	3	8	2
197	WAF 111	39	5	34	77	320	2	3	8	3
201	WAF 115	49	7	27	63	383	2	2	8	3
214	WAF 131	20	8	30	74	362	3	3	8	2
217	WAF 136	24	6	30	74	487	2	2	7	2
219	WAF 138	26	5	30	72	403	3	2	7	2
221	WAF 140	23	6	30	74	377	3	3	8	2
224	WAF 143	31	7	25	74	323	3	2	8	3
230	WAF 151	41	6	30	72	304	3	2	8	2
225	WAF 144	32	7	27	74	376	2	2	8	2
	Local check	57	2	54	87	237	3	3	8	3

DFF = days to flower; DM = days to maturity; BF = beanflies; FT = flower thrips; FW = fusarium spp.; CBB = common bacterial blight

The grain yields of the entries ranged from 200 to 700 kg/ha. WAF 68 (157) and WAF 138 (217) produced the best grain yields of 738 and 487 kg/ha, respectively. The lowest yield (237 kg/ha) was produced by the local check. The 25 entries will be rescreened in *gu'* 1990 along with other seed materials from CIAT.

Empoasca Resistance Nursery

From the 20 entries evaluated in *der* 1988, the 12 most promising lines were retested in *gu'* 1989 (Table 3).

Table 3. Characteristics of Entries in Empoasca Resistance Nursery at Afgoi in *Gu'* Season 1989

Entry names	Harvest plant count	Vigour	DFF	DM	Grain yield (kg/ha)	Disease and pest scores BF	FT	FW	CBB
EMP 185	39	5	31	77	408	2	3	8	2
EMP 188	39	3	33	74	832	2	3	8	3
EMP 190	36	3	37	83	832	2	3	8	3
EMP 193	26	3	37	79	324	2	3	8	2
EMP 196	26	4	34	77	377	2	3	8	2
EMP 197	26	4	37	77	377	2	3	8	2
EMP 198	53	4	37	77	607	2	2	6	2
EMP 84	49	4	38	79	605	2	2	8	2
EMP 135	32	4	37	72	375	2	2	8	2
EMP 164	45	3	37	76	463	2	2	8	2
EMP 175	37	3	34	72	647	2	2	6	2
EMP 14	49	4	37	67	947	2	2	6	2
Local check	57	2	48	88	237	3	2	8	2

DFF = days to flower; DM = days to maturity; BF = beanflies; FT = flower thrips; FW = fusarium spp.; CBB = common bacterial blight

All entries showed moderate to good plant vigour and flowered between 38 and 54 days. Grain yields ranged from 200 to 900 kg/ha. EMP 188 and EMP 14, which were among the earliest entries, produced the heaviest grain yields.

All the entries were highly susceptible to *Fusarium* spp. but there was little common bacterial blight and damage due to beanflies and thrips was small. The 12 lines will be retested in *gu'* 1990.

Discussion

Based on observations of the Bush Bean and Empoasca Resistance Nurseries both seasons are favourable for bean growing, either irrigated or rainfed, but cultivars will probably be needed for these specific purposes.

Furthermore, comparing the grain yields in *der* 1988 to those in *gu'* 1989, the latter season is better, the only drawback being the more severe disease and pest attack in the *gu'* season.

The poor performance in the *der* season is probably due to unusually heavy rainfall, the clayey soil at the Central Agricultural Research Station hampering timely cultural operations.

Although bean research is at a preliminary stage, the lines EMP 14 and Emp 188 from the Empoasca Resistance Nursery and WAF 68 and WAF 138 from the Bush Bean Nursery were the most promising materials. To confirm the consistency of these entries across seasons, the materials will be repeated in *gu'* 1990. The African and International Bean Drought Resistance Nurseries will also be evaluated in *gu'* 1990.

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Bean Production and Research Highlights in Northern Tanzania

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Abstract

In northern Tanzania, bean is produced in Arusha, Kilimanjaro and Tanga Regions. Mean yields of bean in these regions range from 420 to 1140 kg/ha while national yields are between 200 and 700 kg/ha. Bean cultivars, Tengeru 8 and 16 were released for export, while T3, Kabanima, Uyole 84 and Lyamungu 85 cultivars were released mainly for small scale farmers.

In rainfed conditions, bean is planted at the onset of rains. A bean density of 200 thousand plants/ha, spaced 50 cm apart and 10 cm within rows yielded better than bean at 300 or 400 thousand plants/ha. Bean cultivars which performed well in pure stand were also superior in maize/bean associations. Bean sown at two to three seeds/hill at 50 x 20 or 50 x 30 cm spacing yielded the same as the conventional one seed/hill at 50 x 10 cm.

Brestan 60WP, Derosal 60WP and Dithane M-45 fungicides controlled bean anthracnose and angular leaf spot. Fusilade, Furore, Dual 960 and Basagran herbicides supplemented by one hand weeding 35 DAP kept the crop free of weeds. A combination of pre-emergence Galex 500 and post emergence Basagran herbicides provided effective control of weeds in bean fields.

Introduction

Bean is generally grown in association and consumed in rural areas where animal and chicken products are increasingly expensive and not available in sufficient quantity for the low income sector. Common bean, *Phaseolus vulgaris* L., is known by various names, such as french, kidney, haricot, garden, dwarf, snap, string, bush, pole and dry bean. In eastern Africa in general and Tanzania in particular, it is usually referred to simply as bean. Bean is grown extensively in well drained soils, high in organic matter, at altitudes ranging from 450 to 2,000 masl. Well distributed rainfall ranging from 500 to 2,000 mm produces the best bean yields. Temperatures of 21-30^{o}C and a relative humidity of 50% are suitable for good seed filling. Flower abortion, blind pods and split seed testa occur when temperatures are above 30^{o}C. Bean emergence is poor when temperatures are below 20^{o}C and growth ceases at 10^{o}C (Karel *et al.*, 1981).

Bean production is confined to low, medium and high altitude areas of Tanzania. Beans in Tanzania are very important as a complement to carbohydrates thus occupying an important role in providing protein, vitamins and minerals in daily diets. High bean protein content supplements that of non-legume food crops, thus minimizing malnutrition in urban and rural communities.

Increase in food production has not kept pace with population growth, probably due to unfavourable environment and lack of technology in developing countries. World food production has increased annually by 1.5% while population has increased by nearly 3% (Steiner, 1984). Tanzania is no longer self sufficient in food production and needs to import food at least in years when rainfall is insufficient. Rapid population grown has also caused land pressure in productive regions of the country. Consequently, cultivation of bean in association with other crops offers farmers the best option for sustaining daily food supplies.

Bean Production in Northern Tanzania

Increasing food production in northern Tanzania by introducing new technologies relying on commercial inputs has not produced expected results. The new methods were adopted by a few large scale rich farmers but not by the majority of small scale farmers who constitute about 90 percent of the farmers of Tanzania. Since suitable land, labour and capital are limited, it is highly unlikely that farmers in northern Tanzania will grow pure stands of bean. It is important therefore, to increase food production in northern Tanzania by improving existing cropping systems, in which bean is grown in association with maize. Use of FYM, introduction of nitrogen fixing legumes, incorporation of legumes and grass to improve organic matter and application of inorganic fertilizers in these regions are measures to improve bean yields.

National bean yields range between 200 and 700 kg/ha (Jakobsen, 1976) while, on research stations, seed yields of up to 3,000 kg/ha are recorded (Mushi *et al.*, 1989). Reduced seed yields are associated with the low yield potential of landraces, unfavourable weather, poor soil fertility, poor crop husbandry, diseases and pests and unsuitable cropping systems. The main season for bean production in Arusha, Kilimanjaro and Tanga Regions is from March/April, although September/October planting is not uncommon in areas receiving more reliable short rains (for example, Rombo District). Bean:maize associations are widely practised in Kilimanjaro and Tanga and to some extent in Arusha Regions. Maize in association with bean plays an important role in sustaining yield and restoring soil fertility in these regions. Pure stands of bean for export are common in Arusha Region.

While national bean yields are low, mean yields range from 500 to 1,140 kg/ha in Arusha Region (Table 1). Total land area and grain yield in Arusha are larger than in Kilimanjaro Region (Anon, 1989). A number of factors are involved. Firstly, farmers are business-oriented and therefore bean is planted, weeded and harvested without delay. Soil fertility is excellent and is maintained where necessary to ensure high productivity. In areas like Makuyuni, bean for export is sown after the main rains and pesticides are applied, to reduce disease and pest damage and improve seed quality and quantity. In so doing they attract markets and command higher prices.

Arusha also leads in marketing beans in northern Tanzania, followed by Kilimanjaro and Tanga Regions (Table 2).

Bean yields in Kilimanjaro Region fall within the range of national mean yields, suggesting that bean husbandry and environmental conditions are not conducive for high bean yield. Dry spells occurring at the flowering and pod

Table 1. Area ('000s ha), Production ('000s t) and Yield (kg/ha) of Bean in Northern Tanzania.

Region		Year 1984	1985	1986	1987	1988	Mean
Arusha	Area	36.27	48.80	65.66	61.66	79.98	[illegible] 47
	Production	41.41	29.93	58.17	57.17	41.53	[illegible]5.[illegible]4
	Yield	1140	610	890	927	520	817
Lyamungu 85 (on station)	Yield	679	1810	1070	2354	1494	1681
Kiliman-jaro	Area	28.00	21.37	29.03	29.23	40.75	29.68
	Production	13.00	9.10	20.97	28.05	18.36	17.90
	Yield	460	420	720	960	450	602
Lyamungu 85 (on station)	Yield	912	2558	1690	2104	2258	1904
Tanga	Area	35.03	32.84	33.91	33.91	30.58	33.25
	Production	35.03	30.38	33.90	33.90	33.17	33.28
	Yield	1000	920	1000	1000	1080	1000

Table 2. Regional Bean Purchases by National Milling Corporation (NMC) in Metric Tons.

Region	Year 1984	1985	1986	1987	1988	Mean
Arusha	1313	54	370	13472	17048	6457
Kilimanjaro	29	5	16	1068	6233	1470
Tanga	66	110	210	1146	424	391

filling stages reduce yields but can be alleviated by irrigation. Diseases - white mould, anthracnose and angular leaf spot - and insects - foliar beetle, beanflies and pod borers - also reduce bean yields, since farmers cannot afford to control them by chemical means. Tanga Region falls between Arusha and Kilimanjaro in terms of land area under bean production, total grain yield and mean yield per hectare.

Yields obtained from farmers' demonstration plots and on station experiments using improved cultivars and recommended packages range generally from 500 to 3,000 kg/ha (as much as 6 t/ha has been recorded) depending on management.

Research to address and solve bean production constraints is conducted by: Agricultural Research Institutes of the Ministry of Agriculture; Sokoine University of Agriculture (SUA) at Morogoro; Uyole Agricultural Centre (UAC) at Mbeya; and the University of Dar es Salaam. The research highlights outlined below are products of the determination and dedication of scientists from all these institutions.

Bean Research Highlights

Bean Breeding

Bean research was started at Tengeru in northern Tanzania in 1959. Research work was based on white seeded haricot beans for export. Among the achievements of the Northern Research Centre was the release in 1965 of Tengeru 8 and Tengeru 16, which were resistant to bean rust and suitable for canning. In 1971, UAC started a bean research programme focusing on bean selection and agronomic practices in the Southern Highlands. The consequence of this work was the release of T3 (small red seeds and resistant to rust and angular leaf spot) and Kabanima (large red seeds with cream flecks) in 1979 for high altitude and rainfall areas of southern Tanzania. Uyole 84 (small cream seeds) was released in 1984, together with a package of agronomic practices for the same areas.

In 1975, bean work was initiated at Ilonga Research Station under the Grain Legume Improvement Programme. However, the major emphasis was on cowpea, soybean, green gram and pigeon pea. By 1979, the National Phaseolus Bean Research Programme was started at Tengeru and later moved to Lyamungu Agricultural Research Institute. The programme at Lyamungu has released a cultivar, known as Lyamungu 85 (large red seeds with cream flecks, high yield potential, resistance to important diseases, good taste and cooking quality and wide adaptability) and a package of agronomic practices for northern Tanzania. Lyamungu 85 is recommended for low, medium and high altitude areas with medium to marginal rainfall. Canadian wonder is also grown in medium to marginal rainfall areas while Masai Red is grown in medium to high altitude and rainfall areas of northern Tanzania. The programme also established contact with farmers as a direct means of disseminating research information.

Breeding for beanfly resistance

Trials designed to monitor the population dynamics and species composition of beanfly (*Ophiomyia* spp.) populations showed that beanfly numbers were small in early sown crops but rose as the season advanced. *O. spencerella* was the dominant species (87-99%) with *O phaseoli* also present.

On-farm work

In cultivar tests, performance of individual entries differed with season and location but Lyamungu 85, G 5621, Uyole 84 and EMP 86 were the best yielders.

Exploratory trials using a modified minus one design were initiated to quantify the factors limiting bean yield and to explore their interactions. In

Lushoto and Kilimanjaro the full package (improved seed, fertilizer and disease and insect pest control) produced the best seed yield (1069 kg/ha) while the poorest yield (554 kg/ha) was obtained with farmers practice. The two most important factors limiting bean yield in Lushoto were poor soil fertility and the local cultivar.

Farmer participation

Farmers have participated in assessing the production, consumption and marketing characteristics of cultivars and breeding lines in on-farm and on-station trials. Scientists are benefiting from their frankness, openness and suggestions for future trials. Farmer participation and on-farm work confirm the popularity of Lyamungu 85 (Mushi and Edje, in press).

Agronomy

The main objective of the agronomy research programme is to develop agronomic packages that contribute to increased bean production and net return to bean growers. The chief clients are small scale farmers. Commercial large scale farmers receive limited emphasis. Agronomic research highlights are briefly outlined.

Time of sowing of bean in rainfed conditions

Time of sowing of bean in rainfed conditions was investigated for five years to sample the range of conditions associated with drought stress, excessive moisture, insect pests, diseases and weed infestation. The first planting (onset of rains) was generally superior to subsequent plantings (Anon., 1988). Consequently, it was recommended that bean should be sown within the first four weeks of onset of rains to avoid moisture stress due to their early cessation.

Bean spacing and density

Four years of trials showed that a density of 200 thousand plants/ha and a spacing of 50 x 10 cm were superior to 30, 40 and 60 cm spacing between rows and densities of 300 and 400 thousand plants/ha and recommended for subsistence and commercial farmers (Mmbaga *et al.*, 1982).

Screening Bean Cultivars for Maize/Bean Association

It was noted that bean cultivars and breeding lines that performed well in pure stand also performed well in association. Maize yields were not reduced significantly in association with bean (Koinange *et al.*, 1985; Mmbaga, 1989).

Optimum Bean Density in Association with Maize

In five years of trials there were no significant bean seed yield differences among the three densities (100, 150 and 200 thousand plants/ha) examined (Mbuya *et al.*,, 1985; Mmbaga, 1989), suggesting that any of these densities can be used for bean in association with maize, depending on seed and labour availability. However, Mmbaga (1989) obtained the highest total combined maize/bean yield from bean at 150 thousand plants/ha associated with maize at 40 thousand plants/ha.

Effect of number of Bean Plants per Hill on Bean Yield

Work at Lyamungu showed that the yields of bean sown at two (spaced 50 x 20 cm) or three (50 x 30 cm) seeds per hill did not differ significantly from the yield of the conventional spacing of one seed per hill at 50 x 10 cm. Seed yields were less with four seeds per hill, probably due to the more severe within hill competition and a microclimate more favourable for diseases. Since the conventional spacing is more labour and time consuming, two or three seeds per hill are more economical and practical (Mmbaga *et al.*, 1982).

Long Term Yield Sustainability Trials

In rhizobia inoculation trials, seed inoculation and phosphorus application significantly improved nodulation and seed yields.

Plant Protection

Disease Control

Pathology studies focused on two economically important and widespread diseases - halo blight and anthracnose. Breeding for disease resistance is a long term but effective approach to disease control. BAT 317 showed specific resistance to both races 2 and 3 of the pathogen (Gondwe, 1987a). The majority of cultivars and breeding lines with high resistance were small seeded. Resistance to race 3 was more common than to race 2, suggesting the importance of race 2 at Lambo.

The use of fungicide is recommended as a short term measure against anthracnose. Of five fungicides tested, Brestan 60WP and Derosal 60WP consistently showed good control of bean anthracnose and angular leaf spot. Dithane M-45 gave satisfactory control of anthracnose if applied thrice during the growing season. (Gondwe, 1987b). Spraying beans at 14, 28 and 42 days after planting (DAP) with these fungicides reduced anthracnose severity and increased bean yield remarkably.

Insect Control

Breeding for host plant resistance lags behind other breeding activities. Chemicals are recommended for insect control as a short term measure. Thiodan 35EC gives good control of foliar beetle, beanflies, pollen beetles and pod borers. Rogor 50 is recommended where Thiodan gives unsatisfactory control. For food grain storage, Kynakil 1%, is recommended. Fernasan D is recommended for dressing seeds for sowing.

Weed Control

Work on weed control was aimed at herbicides which, applied alone or in combination with other weed control measures, would effectively control weeds in beans at critical stages. The first 35 days of bean growth is the critical period. Fusilade, Furore, Dual 960 and Basagran, supplemented by one hand weeding 35 days after sowing kept the crop free of weeds (Gondwe, 1987c). Galex 500 applied pre-emergence and Basagran post-emergence provided effective control of weeds in bean. Two hand weedings at 14 and 35 days after planting also controlled weeds and improved bean yield.

Extension

Regional and national bean yields are smaller than expected despite progress in research. Farmers continue to use poor management packages and low yielding landraces which are susceptible to diseases and insects. The impact of recommendations from research institutions is yet to be seen in northern Tanzania. There is a time lag between the release of new technology and its adoption by farmers. The time gap will greatly depend on the effectiveness of the extension services. Extension services in these regions are focused more on cash crops than on food crops. Consequently, food crops researchers are promoting their packages directly to farmers in the hope that the package or part of the package will be adopted more quickly.

Future Plans for Bean Research Programme

The programme's main focus continues to be genetic improvement, given its substantial potential impact and broad adaptability. Emphasis will be placed on genetic resistance to diseases (anthracnose, halo blight, bean common mosaic virus, common bacterial blight, angular leaf spot, white mould and rust), insect pests (beanflies, bean beetle and bruchids), low soil fertility and moisture stress. A sub-project to study the genetics of resistance to beanflies was proposed and approved by the SADCC Bean Steering Committee. When the genetics of resistance are established, appropriate plant breeding procedures will be implemented through a combination of introduction, local collection and hybridization. Improved agronomic packages and farmer acceptability of such practices will also be emphasized. The time lag between the release of technology and its adoption must be reduced in order to improve bean production in Tanzania.

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Performances of Elite Bean Lines and Cultivars in the Bimodal Rainfall System of Kagera Region and Their Implications for Selection

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Abstract

In western Tanzania, especially Kagera Region, bean (Phaseolus vulgaris L.) is a very important crop. The region has bimodal rainfall with two bean growing seasons: March to June (long rains) and August to December (short rains). The main season for bean is the short rains. The major concern of the bean breeding program is to identify materials which do well in either or both seasons.

Five advanced lines, five cultivars and a local check were evaluated in both growing seasons of 1986. Agronomic, phenological and morphological data were collected. For all characters except days to flowering, correlations between seasons were very weak. Recommendation of different cultivars for the two seasons is plausible provided the observed trend is consistent across years.

Introduction

In Tanzania, common bean (*Phaseolus vulgaris* L.) is a very important food crop for a substantial part of the population (Karel *et al.*, 1981). The major areas of production are in Kagera, Kigoma, Arusha, Mbeya, Kilimanjaro, Tanga and Rukwa Regions.

Kagera region, in western Tanzania, has altitudes between 1,000 and 1,500 masl (Koinange, 1987). The rainfall pattern of the region is bimodal with two growing seasons (Table 1). The first season extends from March to May (long rains) and the second season from August to December (short rains), with a dry season in between. Most farmers of the region grow bean during the short rains. The main reason for preference for this season is the smaller rainfall and therefore less disease incidence than during the long rains. Also, due to intensive land use, soils are best rested for one season each year.

The breeding programme evaluates introduced bean materials and local landraces. Disease and insect pest resistance, and desirable agronomic, phenological and morphological characters are among the traits scrutinized. The time to the release of new cultivars is long to enable adequate testing of their adaptability and stability across diverse environments. New introductions and local collections are evaluated for one season and the best proceed to preliminary trials with two replications. The best performing lines are then included in advanced yield trials at an increased number of sites covering the major bean growing regions. Superior entries proceed to uniform cultivar trials at an even larger number of sites. The procedure allows reliable assessment of the stability and adaptability of breeding lines across locations and years (Finlay and Wilkinson, 1963; Voysest and Garcia, 1984).

Table 1. Total Rainfall and Mean Maximum and Minimum Temperatures for Each Month of the Two Bean Growing Seasons at Maruku in 1986.

Month	Rainfall (mm)	Temperatures (°C)	
		Maximum	Minimum
Long rains			
March	221.6	25.0	15.7
April	270.8	24.7	15.6
May	228.0	24.0	14.6
Short rains			
October	257.0	24.8	16.0
November	162.9	24.7	16.0
December	188.3	24.7	15.6

The objective of this study was to examine the consistency of performance of entries in uniform cultivar trials in the two different rainfall seasons in Kagera to assess the feasibility of developing a single cultivar suited to both environments.

Materials and Methods

Five bean advanced lines, five cultivars and a local check were evaluated at Maruku in Kagera Region, during the two growing seasons of 1986. In both seasons, a randomized complete block design with four replications was used. Each plot consisted of five rows, five meters long, with spacings of 50 cm between and 20 cm within rows and two plants/hill. Thirty kg/ha N and 60 kg/ha P_2O_5 were applied at planting. Other recommended crop husbandry practices were followed. Phenological and agronomic characters were recorded and analyses of variance and correlations between seasons were computed according to Snedecor (1961) and Gomez and Gómez (1984).

Results and Discussion

Correlations between seasons were large and significant for days to flowering (0.664**) indicating that relative times to flowering of the entries were similar in both seasons. Correlations were very poor for days to maturity (0.240), pods/plant (0.102) and seed yield (0.178), so entries responded differentially to seasons in respect of these characters.

There were significant differences among entries for all characters in both seasons (Tables 2 and 3). Examination of the mean values for the two seasons reveals the reasons for the differences in the correlations.

Table 2. Days to Flowering and Maturity, Pods/Plant and Seed Yields (kg/ha) in Uniform Cultivar Trial at Maruku in the Long Rainy Season, 1986.

Entry	Days to 50% flowering	Days to 85% maturity	Pods/ plant	Seed yields
Canadian Wonder	38.3	80.5	12.0	1433
Selian Wonder	37.5	79.3	15.5	1203
Lyamungu 85	38.0	85.0	18.3	1448
YC-2	37.0	80.0	5.8	1648
T-3	41.5	83.0	14.3	1965
Kabanima	40.8	89.0	19.3	1020
TB 79/509	41.3	79.0	12.0	1161
Selection 8	46.5	80.0	16.5	1261
SD 79/381	38.3	83.0	17.3	2143
Masai Red	46.8	88.0	18.5	1408
Local check	43.5	79.3	22.5	1592
Mean	40.8	82.4	15.6	1480
L.S.D. (P = 0.05)	3.47	1.29	1.39	398

Table 3. Days to Flowering and Maturity, Pods/plant and Seed Yields (kg/ha) in Uniform Cultivar Trial at Maruku in the Short Rainy Season, 1986.

Entry	Days to 50% flowering	Days to 85% maturity	Pods/ plant	Seed yields
Canadian wonder	36	80.0	12.1	1206
Selian wonder	37	74.0	8.3	1396
Lyamungu 85	36	76.0	11.5	2111
YC-2	37	76.0	10.5	1322
T_3	42	89.0	20.5	1481
Kabanima	41	82.0	12.8	1714
TB 79/509	41	87.3	12.3	1245
Selection 8	42	86.0	17.5	1389
SD 79/381	36	84.0	11.0	1231
Masai red	42	89.0	21.0	1821
Local check	38	80.0	12.3	1155
Mean	38	82.1	13.6	1461
L.S.D. (P = 0.05)	1.6	1.52	2.83	243

Selian Wonder, YC-2, Canadian Wonder, Lyamungu 85 and SD 79/381 flowered earlier than the other entries in both seasons, so there was good correlation between seasons. In contrast, in the long rains, Selian Wonder, YC-2, TB 79/509, Selection 8 and the local check were first to mature while, in the short rains, Selian Wonder, Lyamungu 85 and YC-2 matured earliest. Similarly, in the long rains, SD 79/381 produced the heaviest yield, followed by T-3 and YC-2 while, in the short rains, Lyamungu 85 yielded most, Masai Red was second and Kabanima third. In the short rains, seed yields were closely associated with pod number, with Lyamungu 85 and T-3 producing the most pods but, in the long rains, the local checks, Kabanima and Lyamungu 85 produced significantly more pods than most other entries.

The reasons for these differential responses are not clear. The heavier disease pressure in the long rains (Kamala, personal observation) could have contributed, due to differences in disease resistance. Rainfall distribution *per se* and temperature differences (Karel *et al.*, 1981) are other possible explanations. Further trials of the same entries across seasons are required to determine the most appropriate breeding and selection strategies for the bimodal rainfall situation of Kagera.

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Addressing Bean Producers' Problems in the Northern Highlands of Rwanda

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Abstract

Field bean (Phaseolus vulgaris) is a major component in the Rwandan diet, providing 25% of total calories and up to 45% of protein intake. In Rwanda, bean occupies about 25% of the harvested area. Despite its importance, the yield of bean has decreased over the years primarily because of declining soil fertility and its expansion to more marginal land. The present estimated yield is about 800 kg/ha. In an effort to help bean producers increase their production, a series of research efforts were undertaken between 1986-1988. These include: selection of local cultivars; selection of lines from introductions from the International Center for Tropical Agriculture (CIAT) and Agronomic Research Institute of Rwanda (ISAR) for adaptability and farmer acceptability; seed treatment; sorghum-climbing bean intercropping; and farmer-based low input seed multiplication systems. Based on the results of these studies, four climbing bean cultivars are now recommended to farmers of this area. Wide distribution and adoption of them will help to narrow the gap between Rwanda's dry bean production and consumption. This paper describes the highlights of the bean variety trials.

Introduction.

In Rwanda, bean ranks first in terms of area cultivated and fourth in terms of production (Gahamanyi, 1985). In 1983, there were about 307 thousand ha under beans in the country. The total dry bean production is estimated at 224 thousand t (Anon, 1985). Since Rwanda is in deficit in bean production, the demand for additional beans is met by unofficial movements across the border from Uganda and Zaire (Loveridge *et al.*, 1987).

The work area was located in the four eastern communes of Ruhengeri Prefecture (one of 10 principal administrative divisions of Rwanda), namely Butaro, Cyeru, Nyamugali and Nyarutovu, during the years between 1986 and 1988. Approximately three-fourths of the work area lies in the Buberuka Highlands (BH) and the remaining one-fourth in the Central Plateau (CP) region, which are two of Rwanda's 12 major agro-climatic zones (Delepierre, 1975). The area generally has a cool humid climate; the annual average temperature is 18^{o}C, and normally fluctuates between 10 and 26^{o}C. The rainfall is bimodal; the principal rainy season is from March through May, and the second rainy season lasts from September through December. The months of June and July constitute the principal dry season, with another short moisture deficit period during the months of January and February. The total rainfall in the area varies from 1,150 mm to 1,550 mm, with a gradual increase from north to the south.

Soils in the project area are primarily of schist origin. Oxisols are the dominant soil order, interspersed with more shallow Lithic Entisols. Excessively weathered Oxisols are dominated by iron and aluminum oxide clays and tend to be well- drained and acidic with excellent physical characteristics; however, they have poor chemical properties. They are considered to be good for cultivation, provided nutrient and organic matter levels are maintained. These soils are also prone to erosion (Anon, 1987).

Bean of all three growth habits (climbing, semi-climbing and dwarf) is grown in this area. Climbing types are generally planted pure (single cultivar) and in monoculture except when planted in banana groves. When planted as mixtures, the number of components rarely exceeds five or six. Dwarf and semi-climbing types are grown together in mixtures (henceforth referred to as dwarf beans) and a typical mixture contains 12 to 16 different components. In season A (planting time September-October), about 80% of dwarf beans in the BH area are planted in association with maize, while in the B season (planting time April), about one-half is planted in monoculture. Although climbing types yield much more than dwarf types under favorable conditions, the choice between the two depends on many factors such as climate, soil fertility, availability of stakes and farmer preference.

Diagnostic surveys (Franzel *et al.*, 1985; Bizima *et al.*, 1986) conducted in the project area identified the following constraints to bean production: low soil fertility; lack of improved varieties; diseases; difficulties in finding stakes for climbing beans; and traditional cultural practices. Consequently, the initial on-farm trials were designed to address some of these problems.

On-farm trials to evaluate the yields, adaptability and grower acceptability of new bean lines were commenced in 1986B. The aim was to identify 'improved' cultivars resistant/tolerant to certain stress conditions such as soil acidity, disease and drought. By reducing losses caused by these stresses, moderate increase in output is possible. For this approach, no costly inputs are necessary.

There were, of course, other considerations: a) on-farm testing of new materials is relatively risk-free; b) farmers are less reluctant to adopt good cultivars as this does not require any changes in traditional production practices; c) CIAT/ISAR had some promising bean lines available for testing on farmers' fields; and d) on-farm trials would provide an opportunity to become more familiar with farmer practices and existing farming systems so that appropriate interventions could be suggested at a later date.

Materials and Methods

The objectives of the study were explained to the farmer- collaborators before installing trials on their fields. It was made clear that the trials were research and not demonstration and that they would actively collaborate as research partners.

Six climbing and five dwarf bean lines that were previously tested on research stations and in multilocational trials by ISAR/CIAT scientists, and three climbing and one dwarf bean cultivars that the author had identified as promising in farmers' fields, were selected for on-farm testing in the first season's (1987A) trials. On most farms five climbing and/or four dwarf bean lines and cultivars were planted. Each season these trials were installed on an average of 30 farms and each entry was planted on a minimum of eight farms.

Based on the 1987A results (some of the same entries were also tested in our exploratory trial in 1986B), four climbing and three dwarf types were selected for further testing during the three subsequent seasons. These selected entries had out-yielded local cultivar mixtures and had met the selection criteria of the farmers.

Trial Installation and Monitoring

Farmers cultivated the land twice and project technicians and extension personnel helped them to lay out plots. Farmers were supplied with 350 pre-packaged seeds of each entry, which they planted in their traditional way in 2 x 5 m plots: they managed the plots (for example, weeding and staking), but planting and harvesting were done in presence of project personnel. Each farm was visited three to four times to gather data on plant density, disease, number of plants per plot at harvest, number of pods per plant, yield and farmer opinions of the entries tested.

Approximately at full-bloom stage, the per cent total leaf area affected by diseases was estimated. No attempt was made to score each disease individually. At maturity, the plots were harvested in the morning when atmospheric humidity was high, to avoid pod shattering. All plants in a given plot were uprooted and counted; pods containing at least one seed were separated from the plants and counted. The pods from each plot were placed in separate harvest bags and labelled. Field days were organized in which people were invited to participate in evaluation of the entries. Farmers were instructed to thresh and dry the grains as they do normally, but to keep the harvest from each plot separated; these were weighed after two weeks.

Climbing and dwarf types were planted in separate blocks and plots within a block were assigned randomly to varieties. There was only one replication per farm, and each farm was considered a replication. All data were entered on Lotus 1-2-3 and analyzed using appropriate sub-programs of the Statistical Analysis System (SAS-PC). Means separation was by Duncan's Multiple Range Test. In order to obtain a systematic farmer evaluation of the entries, a questionnaire designed by CIAT's sociologist based in Rwanda was used (Voss, personal communication). For this we interviewed 19 farm families who had collaborated with us for at least two growing seasons.

Results and Discussion

Seedling emergence and plant density.

Emergence of the entries averaged 90% and was uniform (Table 1) suggesting that the seeds planted were of good quality, that farmers successfully removed unviable, damaged and diseased seeds prior to planting, that land-preparation was adequate and that planting depth was appropriate and uniform.

At planting time, farmers were asked if we had given them too few or too many seeds to plant. More than 50% of them thought that the seed rate was just about right, while the others thought that the number was too many. However, seedling counts taken on the farmers' own beans (dwarf and climbing), showed that they had planted at least 20% more seeds than we did. Our seed rates varied from 100 kg (for G 2333) to 155 kg/ha (for Puebla). A separate study conducted by us using dwarf beans showed that densities between 200 to 600 thousand plants/ha did not significantly affect grain yield (unpublished). In the work area, a density of 250 thousand plants/ha seemed to be adequate. If farmers could be persuaded to reduce seeding rates by 20% (about 30 kg/ha), national savings of 10 thousand tonnes seed/year could be achieved without reducing grain yields. This will reduce considerably the country's present annual dry bean deficit of 36 thousand tons (Loveridge *et al.*, 1987).

Table 1 shows the number of seedlings that emerged and the number of plants counted at harvest; the difference between the two numbers represents loss of plants due to disease, insect pests, mechanical damage and other factors. Although seedling survival rates varied from farm to farm, between 60 and 80% of emerged seedlings reached maturity. One of the reasons why farmers plant greater than needed densities could be to compensate for this plant loss.

Table 1. Seedling Emergence, Plant Survival and Number of Pods (Numbers/10 m^2) of Climbing Bean On-Farm in the Northern Highlands of Rwanda in 1987 and 1988.

	1987A			1988B		
Entries	Seedlings	Plants	Pods	Seedlings	Plants	Pods
G 858	320	204	1060	330	265	1359
Puebla	350	211	897	330	269	1237
G 2333	310	219	1147	320	250	1321
Mwirasi[a]	330	253	1318	330	254	1155
Local	340	225	982	320	249	1102

[a] data are based on a minimum of 10 tests except for Mwirasi (only 4)

Grain Yield

Climbing bean yields from four seasons are presented in Table 2.

Although nine climbing bean entries were tested in 1987A, only those entries which produced yields higher than local cultivars are presented here. Three of the four entries selected (G 858, G 2333 and Puebla Criollo 444) were introduced from CIAT and, subsequently, tested by ISAR on research stations, while the fourth, a cultivar called Mwirasi, was selected by us locally. We saw Mwirasi growing on a few farms in Nyarutovu commune during our first exploratory season (1986B), and this cultivar was unknown to farmers in the neighboring communes. This is an early maturing cultivar with excellent yield potential and has medium- sized, violet-colored grains. Since it was already being grown in the area, its adaptability and acceptability were not in question. We planted this cultivar in 1987A on only four farms, where it produced the largest yield. During the next two seasons we could not plant this cultivar because seeds were unavailable; however, a few farmers were encouraged to multiply its seeds for subsequent testing.

In season 1987A, three CIAT/ISAR lines and Mwirasi produced yields over 2100 kg/ha compared to 1684 kg/ha for local cultivars or mixtures. The four seasons' average yields for the three CIAT/ISAR varieties exceeded 2300 kg/ha compared to 1859 kg/ha for local mixtures (Table 2). It should be mentioned here that our yields were considerably more than the area's estimated average climbing bean yield of about 1400 kg/ha. This is primarily because the farmers took a little extra care of the test plots and harvest losses were kept to a minimum.

In the dwarf bean trials (Table 3), Kirundo and Ikinimba had small but consistent yield advantages over local mixtures in both seasons. However, Kirundo is susceptible to halo blight and Ikinimba to rust. Moreover, some farmers did not like the seed of Ikinimba, which is black. In season 1987A, G 11060 produced a slightly better yield than the local cultivar, but its small grain size and long growing period did not appeal to farmers.

Table 2. Grain Yields (kg/ha) of Climbing Bean Entries On-Farm in the Northern Highlands of Rwanda in 1987 and 1988.

	Seasons					
Entries	1987A	1987B	1988A	1988B	Mean	% Local
G 858	2113ab	2242bc	2925ab	2339a	2422	130
Puebla	2161ab	2339ab	2995a	2057a	2388	128
G 2333	2101ab	2544a	2643b	2000ab	2322	125
Mwirasi	2326ab	NT	NT	1639bc	1982	107
Local	1684b	1993c	2182c	1577c	1859	100
No. of tests	12	22	21	13		
C.V. (%)	26.4	18.8	18.0	24.8		

Means within a column followed by the same letter are not significantly different according to Duncan's Multiple Range Test ($P<0.05$); means for Mwirasi are based on four tests only.

Foliar Diseases

The per cent total leaf areas affected by all foliar diseases are shown in Table 4. The predominant foliar diseases of beans in the area are ascochyta (*Phoma exigua* var. *diversispora*), anthracnose (*Colletotrichum lindemuthianum*), angular leaf spot (*Phaeoisariopsis griseola*), floury leaf spot

Table 3. Grain Yields (kg/ha) of Dwarf Bean Entries On-Farm in the Northern Highlands of Rwanda in 1987.

Entries	Seasons 1987A	1987B
Kirundo	945(16)[a]	1560(9)
Ikinimba	832(12)	1410(19)
Kilyumukwe	713(16)	NT
Urubonobono	645(14)	NT
G 11060	847(8)	NT
Local mixture	758(21)	1274(24)

[a] the numbers in the parenthesis are the numbers of on-farm trials

(*Mycovellosiella phaseoli*) and, to a lesser extent, rust (*Uromyces appendiculatus*) and viral diseases. In terms of yield reduction, anthracnose and the viral diseases are most serious. Fortunately, we had little problem with virus diseases during the study period. The results, as expected, indicated that the incidence of diseases varied from one season to the next and that some entries were more tolerant to diseases than others. Overall, G 2333 and G 858 appeared to have most resistance against diseases. The correlations between per cent total leaf area affected by foliar diseases and bean yields, however, were not significant.

Table 4. Per Cent Total Leaf Areas affected by Diseases of Entries in On-Farm Trials in the Northern Highlands of Rwanda between 1987 and 1988.

Entries	Seasons 1987A	1987B	1988A	1988B	Mean
G 858	2.81c	1.31a	5.56c	9.38ab	4.77
Puebla	4.34ab	1.81a	7.90b	9.30b	5.84
G 2333	3.03c	1.33a	7.23bc	5.52c	4.28
Mwirasi	3.64bc	NT	NT	11.30a	7.47
Local	2.64c	1.72a	11.13a	11.25a	6.69

Minimum of 12 tests, except for Mwirasi in 1987 A, which was based on only four tests; means within a column followed by the same letter are not significantly different according to Duncan's multiple range test ($P<0.05$)

Farmer evaluation of entries in on-farm tests

The questionnaire for evaluation was designed to determine: 1) the criteria farmers use to evaluate bean cultivars; and 2) their opinion of the three test entries chosen primarily for their yield performance.

The criteria that farmers of the project area were found to use to evaluate bean varieties, in order of importance, were: grain yield; grain color; grain size; resistance to disease (high humidity); maturity period; and taste of dry beans.

Farmers use the same criteria to evaluate dwarf, semi-climbing, and climbing bean. Yield is the most important criterion, while the ranking of other characters could change from one farmer to the next. Whenever farmers were asked to evaluate a standing crop of beans, they invariably responded by saying, "let's wait till the harvest time". Besides the six criteria listed above, the farmers also mentioned: growth habit (erect or procumbent for dwarf; light or heavy for climbing); drought tolerance; performance on poor soil; edibility of leaves; and quality of green pods

The farmers liked all three CIAT/ISAR introductions and Mwirasi primarily because of their high yields. They appreciated the grain color of all four entries, the large grain sizes of Puebla and G 858, and the earliness of G 2333 (Table 5). However, they expressed reservations about the small grain size of G 2333, and the long maturity period of G 858. They also thought G 858 was more susceptible to high rainfall (diseases) than the other entries. The maturity periods of these entries in the BH area were about 110 days for G 2333, 115 days for Mwirasi, 126 days for Puebla Criollo and about 135 days for G 858 while, in CP zone, all matured about ten days earlier. Plants of G 2333 and Mwirasi are relatively light weight and could be adequately supported by *Pennisetum* stakes, the most commonly used stakes in the area; while for the heavier G 858 and Puebla Criollo plants, wooden stakes would be desirable.

Table 5. Farmer Evaluations of Three Climbing Bean Entries in On-Farm Trials in the Northern Highlands of Rwanda.

Puebla	G 2333	G 858
Positive aspects[a]		
Good grain yield	Good grain yield	Good grain yield
Good grain color	Disease resistance	Good grain color
Disease resistance	Good grain color	Large grains
Large grains	Early maturing	
Pods tasty	Lot of pods	
Leaves edible	Resists drought	
Resists drought		
Negative aspects[a]		
	Small grain size	Late maturing
		Low disease tolerance

[a] listed in order mentioned by the farmers

Farmers rated Puebla best, followed by G 2333 and G 858. These three entries, and the local cultivar, Mwirasi, have farmer approval. Because of the inadequacy of Rwanda's present seed multiplication and distribution systems, it has become a bottleneck to meet farmer demands for seeds of bean cultivars (Paul and Grosz, 1987). We have responded to their requests through the introduction of a low input farmer-based seed multiplication system, designed specifically to multiply seeds of these four bean varieties (Paul, 1987).

Some of the collaborating farmers who never grew climbing bean before are now planting these as they have seen for themselves their yield advantages over the dwarf types (under normal conditions the climbing bean produces about 50% more than the dwarf types) (Table 6). This is definitely a step in the right direction.

Table 6. Grain yields (kg/ha) of climbing bean entries in association with banana in on-farm trials in the northern highlands of Rwanda in 1988A.

Puebla	G 858	G 2333	Mwirasi
1295	1365	1432	1842

Means of 11 tests

Acknowledgements

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SUMMARY OF DISCUSSIONS

Rono and Shakoor

Macrophomina is featured as an important problem in arid areas of Kenya and resistant cultivars are not yet available. Interspecific crosses with *Phaseolus acutifolius* had been suggested but CIAT lines having macrophomina resistance may be more effective in the short term. It was also indicated in the presentation from Sudan that late planting and seed dressing with Aldrex reduced the problem.

It was suggested that methods of water conservation and irrigation developed in the Sudan may be appropriate also for dry areas of Kenya.

Rachier

A point of clarification on the levels of P, N and K was that K was high due to the original parental material so had not been leached to the same extent as N and P.

In connection with the lack of climbing bean in Kenya, it was stated that maize is considered the more important crop and farmers do not want to risk reducing maize yields by intercropping with vigorous climbing bean types with heavy demands on soil nutrients.

Salih *et al.*

An interesting feature of bean storage in northern Sudan is that bean bruchids die after hatching, so there is no problem of storage pests. More work is needed to determine the causes of bruchid mortality. There are, however, serious viral problems of bean.

It was also noted that climbing bean has not yet been introduced into Sudan.

Bean production in Sudan will only be increased by use of state farms, since higher value crops compete for land.

Farah and Abikar

Phaseolus vulgaris a new bean to Somalia and therefore it is difficult to determine farmers' preferences. A survey is required to establish seed type preferences and farmers' priorities.

Mmbaga *et al.*

It was suggested to relate rainfall distribution to planting of intercrops. Also to determine why farmers tend to grow beans only in the short rains. Previously there was no interaction between research workers and farmers but now demonstration plots are being used. The system in Rwanda presents a good model of how to go on-farm.

Paul

Results from Rwanda illustrate the value of sorghum as a support for climbing bean, especially when suitably arranged.

It was demonstrated how on-farm research helped researchers in releasing acceptable cultivars and introducing new technology. On farm results also demonstrate that some farmers' problems are not fully appreciated. For example: farmers use up to 600,000 plants/ha when researchers had assumed that farmers plant low populations; and failure of adoption of a cultivar by farmers may be due to its lack of adaptation to the farmers' environment.

Genotype x Environment Interaction and Yield Stability in Haricot Bean Cultivars in Ethiopia

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Abstract

Three sets of bean cultivars and advanced lines, grouped according to seed type, were grown at various locations in Ethiopia in 1988 and 1989 to examine their performance across a range of environments. Analysis of variance showed significant genotype x environment (G x E) interactions for all six trial series. The 1988 Large Seeded Bean National Variety Trial (LSB-NVT) was chosen for detailed stability analysis, regressing entry mean yields on location mean yields (environment index). In 1988, the mean yields of entries varied from 1365 kg/ha to 2304 kg/ha. The regression accounted for 80 to 98% of the variation in their yields across locations. Only two entries had regression coefficients significantly different from unity. Stability analysis was also performed on entries common to the LSB-NVT in 1988 and 1989. Entry mean yields varied from 1624 kg/ha to 2572 kg/ha. Regression on the environmental index again accounted for most of the variation in yield across locations (86-98%). Only two of the regressions differed significantly from unity. Diacol Calima and A 483 had most stable performance across environments. A 410 and A 262 appeared most suitable for favourable environments and Brown Speckled for poorer ones. Stability analysis can aid choice of cultivars for specific or general adaptation.

Introduction

In the major bean growing areas of Ethiopia, variation in length of growing season, as a result of rainfall distribution and elevation, is wide. The Rift Valley in central Ethiopia is the main bean producing area. Here, white pea bean is an important cash crop for small farmers. In eastern Ethiopia, beans of various colours are grown, mainly for local use. In western areas, climbing beans are grown, for consumption as green pods.

Diverse growing conditions can be expected to cause differential responses among a set of bean materials grown across locations and years, expressed as significant G x E interactions. Significant G x E interactions may reflect differences among materials in stability. In addition to some desired yield level, stability of performance is a desirable property of genotypes to be recommended for general cultivation and should be considered during selection (Abebe *et al.*, 1984a; Singh and Chaudhary, 1985; Cooper, 1989).

Stability analysis is most often by regression techniques, of which the Eberhart and Russell (1966) model is an example. Eberhart and Russell defined a stable genotype as one with a regression coefficient close to one and minimum deviations from regression.

This paper considers the levels and stabilities of the yields of six sets of bean cultivars and breeding lines grown at several locations in Ethiopia in 1988 and 1989.

Materials and Methods

The seed yields of entries in three series of National Variety Trials (NVT) were used in this study. They were the White Pea Bean NVT (WPB-NVT), the Large Seed Bean NVT (LSB-NVT) and Different Coloured Bean NVT (DCB-NVT). Entries and locations differed among series and between seasons - their numbers are shown in Table 1.

Table 1. Number of Entries in and Locations of National Variety Trials in Ethiopia in 1988 and 1989.

	1988		1989	
Trial	Entries	Locations	Entries	Locations
WPB-NVT	8	10	9	7
LSB-NVT	8	7	8	7
DCB-NVT	10	7	10	8

The locations represented diverse temperatures, rainfalls and altitudes (Table 2).

Table 2. Rainfall and Maximum and Minimum Temperatures during the Growing Season (June to October) and Altitudes of some Locations of LSB-NVT in 1988 and 1989.

		Temperatuces (°C)		
Location	Mean rainfall (mm)	Minimum	Maximum	Altitude (masl)
Awassa	582	12.8	25.2	1700
Bako	800	14.5	25.3	1650
Jima	1154	12.4	23.4	1750
Melkassa	580	14.9	27.1	1550
Ziway[a]	508	13.9	25.1	1650

[a] Means of 14 growing seasons, 1970-83

The trials were all randomized complete block designs with four replications. Plot sizes were 6 rows of 6 m length with 40 cm spacing between rows. The centre four rows were harvested for grain yield (IAR, 1990). A combined analysis of variance was computed for grain yield to determine the statistical significance of the interactions between the entries and the environments. Stability analysis was conducted on the grain yields from the LSB-NVT according to Eberhart and Russell (1966) by regressing the seed yields of individual entries on an environmental index derived from environment mean yields. This led to the following parameters: mean yield ($\bar{x}$); the regression coefficient (b), the standard error of b (s_b); and the coefficient of determination (r^2). The regression coefficient of each entry was tested for its deviation from unity using a t test.

Results and Discussion

The analysis of variance across sites revealed significant G x E interactions for all six series of experiments (Tables 3 and 4).

Table 3. Mean Squares from Combined Analyses of Variance of Grain Yields (kg/ha) of Entries in Bean NVTs in Ethiopia in 1988.

	WPB-NVT		DCB-NVT		LSB-NVT	
Source	df	ms	df	ms	df	ms
Environments	9	38.42***	6	129.19***	6	75.76***
Genotypes	7	2.96***	9	8.21***	7	10.36***
G x E	63	1.49*	54	1.94***	42	3.28***
Error	210		189		147	
CV (%)		22		23		29

*, *** significant at P = 0.05 and 0.001, respectively.

Stability analysis was then performed, but only data from the LSB-NVT are presented, as the entries in this group showed the greatest variation in stability parameters.

In 1988, location mean yields for the LSB-NVT ranged from 270 kg/ha at Jima to 3269 kg/ha at Awassa (Table 5). The grain yields of the seven potential replacements for the currently recommended cultivar (Brown Speckled) were all significantly greater than the yield of the check at one or more locations. Four of the seven locations had coefficients of variation of 35% and above.

Regression on the environmental index explained 80-98% of the variation in yields of entries across locations (Table 6).

Table 4. Mean Squares from Combined Analyses of Variance of Grain Yields (kg/ha) of Entries in Bean NVTs in Ethiopia in 1989.

	WPB-NVT		DCB-NVT		LSB-NVT	
Source	df	ms	df	ms	df	ms
Environments	6	19.31***	7	110.60**	6	66.10***
Genotypes	8	4.59**	9	18.46***	7	11.43***
G x E	48	2.54***	63	2.98***	42	2.51***
Error	168		216		147	
CV (%)		20		19		19

, * significant at P = 0.01 and 0.001, respectively.

Table 5. Grain Yields (kg/ha) of Entries in LSB-NVTs in Ethiopia in 1988.

	Locations							
Entries	AM	AS	AW	BK	JI	MEL	ZW	Mean
Aquascalientes 13	892	1145	1823	623	250	3112	2391	1462
Acc. No. 3142-3	1975	604	3550	205	245	3337	1806	1675
Diacol Calima	1345	1318	3438	708	201	3039	2745	1826
A 410	1387	1353	3844	574	516	3912	3004	2084
A 262	2113	1759	4807	588	490	4246	2127	2304
A 483	2513	1708	3116	618	147	3185	2403	1955
AND 289	606	1040	3284	846	185	3052	2572	1655
Brown Speckled	1304	853	2207	770	127	2086	2128	1365
S.E.±				259.9				98.2
C.V. (%)				29.0				
Mean	1517	1223	3269	617	270	3[illegible]46	2397	
S.E.±				138.8				

Underlined yields are significantly greater than the yields of Brown Speckled at P = 0.05 at individual locations; AM = Ambo, AS = Assossa; AW = Awassa; BK = Bako; JI = Jima; MEL = Melkassa; ZW = Ziway

The regression coefficients differed significantly from unity only in the cases of A 410 (larger than one) and Brown Speckled (smaller than one). The regression coefficients of all other entries were close to unity.

Five entries in the LSB-NVT in 1988 were included again in 1989. Estimates of stability parameters across five locations over two years are shown in Table 7. The coefficients of determination (r^2) ranged between 86 and 97%.

A 262 had a b value significantly greater than unity and the b value for Brown Speckled was again significantly less than one. The b values of all other entries did not differ significantly from one.

Table 6. Stability Analysis for Entries in LSB-NVT at Seven Locations in Ethiopia in 1988 - Mean Yields, Coefficients of Determination (r^2), Regression Coefficients (b) and Standard Errors of b (s_b).

Entries	Mean yield (kg/ha)	r^2	b	s_b
Aquascalintes 13	1462	0.80	0.76	0.169
Acc. No. 3142-3	1675	0.92	0.02	0.151
Diacol Calima	1828	0.98	1.02	0.073
A 410	2084	0.98	1.21	0.077
A 262	2304	0.92	1.32	0.179
A 483	1955	0.88	0.92	0.153
AND 289	1655	0.91	1.01	0.140
Brown Speckled	1365	0.92	0.66*	C.084

* Significantly different from 1.0 at P = 0.05.

Table 7. Stability parameters for five common entries in LSB-NVT at five locations in Ethiopia in 1988 and 1989 - mean yields, coefficients of determination (r^2), regression coefficients (b) and standard errors of b (s_b).

Entry	Mean yield (kg/ha)	r^2	b	s_b
Diacol Calima	1970	0.97	0.98	0.061
A 410	2274	0.94	1.13	0.099
A 262	2572	0.98	1.34*	0.073
A 483	2039	0.94	0.95	0.088
Brown Speckled	1624	0.86	0.61**	0.087

*, ** significantly different from 1 at P = 0.05 and P = 0.01

Considering both sets of data, with these entries and these environments, it appears that regression on the environment index accounts for a very high proportion of the variation in yield across environments, so performance is highly predictable (Abebe *et al.*, 1984b). A 262 and A 410 produce the heaviest mean yields, which are relatively better than those of other entries in favourable environments, while Brown Speckled yields better than other entries in poor environments. Such information is important to ensure that cultivars that are candidates for release are adapted to the situations in which they will eventually be cultivated.

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Yield Stability of Common Bean in Uganda

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Abstract

The overall performance and stability of yield of 25 bean landraces, cultivars and advanced lines were assessed with the intention of identifying those suitable for release. These were grown at five locations for three seasons. Most genotypes performed poorly and the genotype x environment interactions were significant. Drought during flowering and diseases, especially black root, may have reduced the yields of some entries. The best yielders tended to be small-seeded and therefore, not very acceptable to farmers and consumers. G 13671, Rubona 5 and White Haricot were provisionally recommended for release taking into account farmer and consumer preferences.

Introduction

Common bean (*Phaseolus vulgaris* L.) is grown over a wide range of ecological zones in Uganda (Rubaihayo *et al.*, 1981). The testing of breeding lines across locations and seasons is a prerequisite for cultivar release. Though such testing allows for selection of stable genotypes (Eberhart and Russell, 1966), farmer and consumer requirements also have to be taken into account. The seed characters, size and colour, and culinary attributes, taste, cooking time and overnight storability of cooked beans, are some of the reasons for farmers' maintenance of favourite but poor yielding landraces (Kisakye *et al.*, 1987). Though introduced heavy yielding genotypes may prove stable across locations, their release must be limited to particular zones where their seeds are acceptable.

For characters such as yield, GxE interaction causes variation in the relative performance of lines across locations and seasons reflected in changes in the relative ranking of the lines or in the magnitude of the differences among them from one environment to another (Nguyen *et al.*, 1980). There are several methods of determining stability parameters on which cultivar recommendation can be based.

Finlay and Wilkinson (1963) used regression coefficients (b) alone as measures of both stability and adaptation. They considered cultivars with b values less than unity to be above average in stability and relatively better adapted to unfavourable environments, while cultivars with b values greater than unity are below average in stability and better adapted to favourable environments. Cultivars with b values equal to unity, they considered average in stability and either poorly or well adapted to all environments, depending on the cultivar mean yield.

Eberhart and Russel (1966) suggested that yield stability can be measured by the regression of individual cultivar yields in different environments on an environmental index. A stable cultivar was defined as one with a regression coefficient of 1.00 and a mean square deviation from regression equal to zero.

The use of the regression coefficient as a measure of adaptation is of particular importance in areas where management, soils or climatic differences cause distinct differences in yield (Bilbro and Ray, 1976). Cultivars with b values greater than unity could be recommended for areas with favourable conditions and good crop management, in this case the regression coefficient being a measure of adaptation rather than of stability. Such an approach is appropriate in Uganda where attempts have been made to separate farmers into different recommendation domains (Kisakye *et al.*, 1987). Since the regression coefficient is a measure of response to varying environments (Langer *et al.*, 1979), the mean yield and regression coefficient are sufficient for selection of desirable genotypes.

The objectives of these trials were to evaluate the yields and stability of yields of landraces and introduced cultivars and advanced lines. Diseases are a major limiting factor to bean production in Uganda (Rubaihayo *et al.*, 1981) and variation in reactions across locations is useful in interpreting variations in yield. With most valuable breeding lines lost, accompanied by a pressing demand for new cultivars, breeders resorted to the evaluation of introductions with some adaptation to the region. The trials were conducted at eight locations but, since data were incomplete, the results from only five are reported. Regression coefficients were used to compare the stability and adaptation of the landraces and introductions with those of the recommended cultivar, K20.

Materials and Methods

The entries included: 14 lines that produced seed yields over 1000 kg/ha in the first African Bean Yield and Adaptation Nursery (AFBYAN) in 1986; seven landraces; and four other promising lines (BAT 1220, BAC 36, G 2316, and CATU). They were tested in a triple lattice design at five locations for three seasons (1987B, 1988A and 1988B) at five locations. Plots consisted of 4 rows of 4 m length and the spacing was 60 cm x 10 cm. Disease records were taken on a 1-9 scale at R7. Samples of seed were presented to farmers from Rakai, Mpigi, Luwero and Kabale districts to indicate their preferences and reasons for rejection of particular varieties. Stability analysis of grain yields was performed according to Eberhart and Russell (1966).

Results and Discussion

The mean seed yields of entries at each location over three seasons are presented in Table 1. There were significant differences among seasons, the largest yields being recorded in 1988A (672 kg/ha compared with 622 kg/ha in 1987B and 590 kg/ha in 1988B). The season x entry interaction was not significant, indicating that seasons did not affect genotypes differentially, though this may reflect the small size of the sample (three seasons). CATU, BAC 36 and G 13671 did show a tendency to perform better in poor yielding seasons.

Table 1. Mean Yields (kg/ha) of 25 Entries at Five Locations for Three Seasons.

Entry	Locations				
	Kawanda	Kamenya-migo	Bukalasa	Bulindi	Rubare
Black Dessie	549	395	446	594	368
Red Wolaita	351	351	495	689	318
BAT 1220	716	601	832	857	707
BAC 36	718	572	804	758	771
BAC 76	556	444	1434	1128	910
T-3	483	328	470	565	425
CATU	807	534	1152	1114	1350
ZPV-292	399	348	738	661	435
Carioca	575	423	1044	937	457
Urubonobono	660	589	827	728	683
Kilyumukwe	467	474	609	615	602
A 197	576	432	1013	604	529
Nain de Kyondo	587	558	780	968	994
Muhinga	460	324	472	402	383
G 2316	594	503	750	839	864
G 13671	678	590	857	910	1060
Rubona 5	560	531	819	778	484
White Haricot	504	474	1057	992	885
Black Haricot	826	594	882	1024	598
Sebuliba	475	382	576	555	365
Kampulike Purple	347	320	459	525	293
Namunye Red	557	380	736	661	491
Kampulike Yellow	570	285	715	573	385
Mutike	459	447	882	654	750
K20	363	426	514	520	300
Mean	557	452	775	746	616
LSD (P = 0.05)	168.1	115.5	180.2	187.3	287.6
C.V. %	32.4	27.4	25.1	26.9	50.1

Stability analysis was conducted on the combined data Table 2 and Figures 1 and 2. The b value of K20 was much less than unity and its deviations from regression not significantly different from zero, indicating that its seed yield was above average in stability across environments though its mean yield was far below average. The b values for G 13671 and Rubona 5 were close to unity, their deviations from regression were small and their seed yields much larger than that of K20. In contrast, although the deviations from regression of White Haricot did not differ from zero, its b value was much greater than unity, indicating better adaptation to more favourable environments or otherwise ability to produce better yields than other entries with larger inputs, more favourable weather and less disease pressure, especially from BCMV.

Figure 1. Regressions of Grain Yields of Recommended Cultivars on Environmental Index.

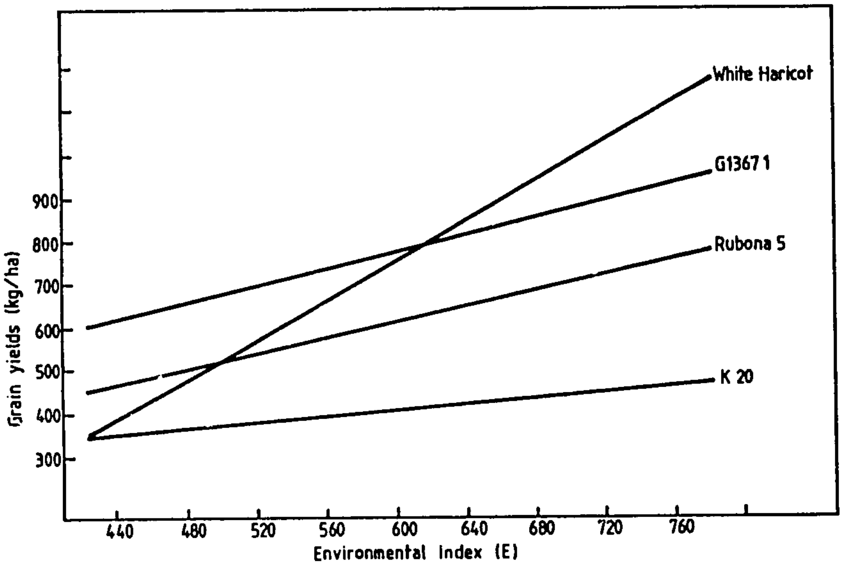

Figure 2. Relationship between Regression Coefficients (b) and Mean Yields of 25 Entries.

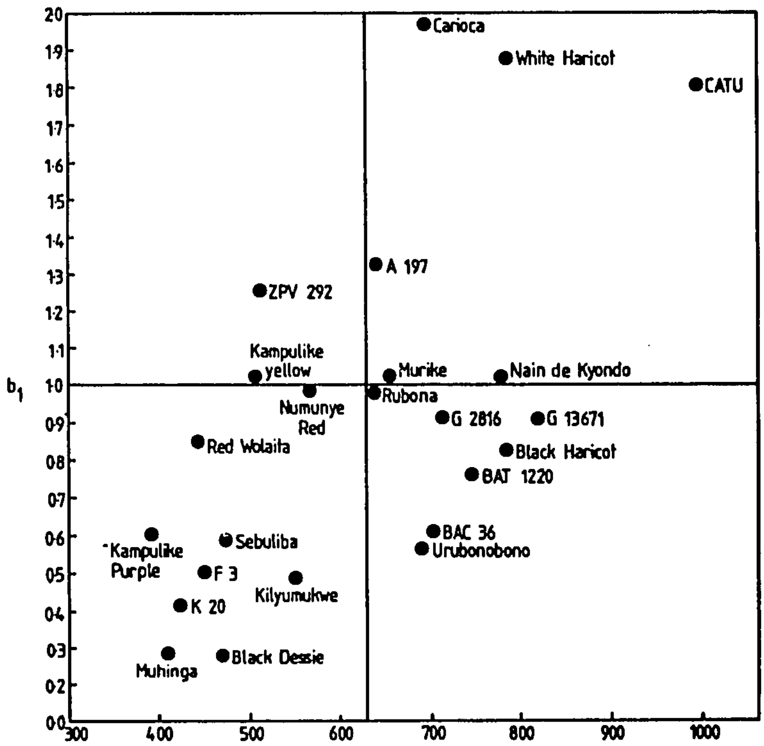

Table 2. Mean Grain Yields (kg/ha), Regression Coefficients (b) and Standard Errors ($SE_b\pm$) for 25 Entries in 15 Environments.

Entry	Mean yield (kg/ha)	b values	$S.E._b\pm$
Black Dessie	471	0.278	0.393
Red Wolaita	441	0.854	0.465
BAT 1220	743	0.763	0.115*
BAC 36	725	0.604	0.190*
BAC 76	895	2.981	0.473
T-3	454	0.508	0.243*
CATU	991	1.817	0.939
ZPV-292	516	1.253	0.217*
Carioca	688	1.966	0.520
Urubonobono	697	0.563	0.077*
Kilyumukwe	553	0.494	0.168*
A 197	631	1.325	0.611
Nain de Kyondo	774	1.027	0.673
Muhinga	408	0.286	0.205*
G 2316	710	0.909	0.443
G 13671	819	0.910	0.631
Rubona 5	634	0.978	0.361
White Haricot	783	1.888	0.424
Black Haricot	785	0.837	0.440
Sebuliba	470	0.592	0.247*
Kampulike Purple	389	0.600	0.262*
Namunye Red	565	0.998	0.207*
Kampulike Yellow	505	1.058	0.428
Mutike	656	1.089	0.398
K20	425	0.422	0.341

* significantly greater than zero at $P = 0.05$

Differences in deviations among entries were due mainly to specific genotypic responses to environments and especially to differences in disease pressure and available moisture during pod-filling. The mean yields of all entries were heavily weighted by the similar responses of a few entries, resulting in large deviations from the regression of other entries in some environments.

Though the mean yield of CATU was significantly greater than all other entries in the trial, its seed size and colour are unacceptable. White Haricot and G 13671 had yields not significantly different from eachother and were among the top five entries. Rubona 5 had significantly greater yield than K20, while its seed colour and size were similar to seeds of K20.

Comments of farmers and consumers from the districts of Rakai, Mpigi, Luwero and Kabale on growth habit, maturity period, seed colour and size and taste, led to the recommendation for release of G 13671, White Haricot and Rubona 5.

G 13671 (large-seeded and heavy yielding) was recommended for Kabale district farmers who did not object to the inconsistency in its seed colour pattern as did farmers in other districts. G 13671 is tolerant to BCMV and is not affected by black root. White Haricot is readily marketable and well appreciated for its taste and fast cooking but suffers from black root and its storability once cooked is very poor.

Four major diseases were observed. Common bacterial blight (CBB) and angular leaf spot (ALS) reactions were significantly greater at Kawanda and Bukalasa than at Kamenyamigo and Rubare. Rust was more serious at Bukalasa and Rubare. At Rubare and Kamenyamigo, there were significant differences among entries in their rust and BCMV reactions but not in ALS and CBB. At Bukalasa and Kawanda, of these four diseases, entries differed significantly only in their BCMV reactions. Heavy yield and multiple pest resistance are important criteria for the release of new cultivars.

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Evaluation of Dry Bean (Phaseolus vulgaris L.) Cultivars in Sudan

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Abstract

Dry bean (Phaseolus vulgaris L.), locally known as fasulia, is grown mainly in northern Sudan with major production in the Shendi-Berber area. The indeterminate baladi type with white or cream coloured flowers and white, medium, flat seeds is the main cultivar. Introduction, local collection and single plant selection were employed to identify high yielding genotypes with tolerance to salt toxicity, curly top disease and high temperature. Introductions were grouped into three categories: white-seeded, with much similarity to the baladi type; non-whites, with small red, mottled and dark red kidney seeds; and pea beans including navy types. Selection for tolerance to diseases and excess salt culminated in the release and adoption of Ro/2/1 as the standard fasulia cultivar in the northern region to replace the baladi type. Location affected genotype performance and dry bean quality. Attempts to grow bean in new areas south of Khartoum were encouraging but more research and breeding work are needed for these areas.

Introduction

Dry bean (*Phaseolus vulgaris* L.), locally called *fasulia*, is one of the most important grain legumes of the Sudan, with major production areas in the northern region. It comes second only to faba bean in both area and production. Other legumes grown in the northern region include chickpea (*Cicer arietinum*), dry pea (*Pisum sativum*) and lupin (*Lupinus termis*). Lentil (*Lens culinaris*), cowpea (*Vigna unguiculata*) and pigeon pea (*Cajanus cajan*) are grown on a small scale by a few farmers and on research stations.

Within the Northern Province, 97% of the total *fasulia* acreage is in Shendi-Berber with an average production estimate of 1.3 tons/ha. The *baladi* type is grown, indeterminate, with white or cream-coloured flowers. It has medium size, white, flat seeds measuring 1-1.2 cm in length and weighing 20-23 g per 100. It is grown as a winter crop on flooded basins after the flood recedes or by irrigation using lift pumps. Production, area and yield are shown in Table 1.

The continuous decline in area is most likely due to: replacement by faba bean because of its higher price; heavy bean yield losses from insects, especially whitefly which transmits virus diseases like curly top; salt toxicity in the Karu soils limiting production to alluvial rich soils with low salt content, near the Nile; lack of certified seed, causing farmers to use their own inferior stocks or seeds from local markets; and, poor cultural practices and inferior cultivars resulting in poor yields.

Table 1. Field Bean (*Phaseolus vulgaris*) Area, Production and Yields in the Sudan from 1961 to 1980.

Year	Area (ha)	Production (t)	Yield (kg/ha)
1961	5820	8259	1419
1962	5437	7664	1410
1963	5880	6006	1021
1964	6941	10197	1469
1965	7206	10037	1393
1966	6720	11200	1667
1967	5880	6202	1055
1968	4200	4000	952
1969	2940	2002	681
1970	3360	4000	1190
1971	3780	3996	1057
1972	3360	4960	1476
1973	2520	4002	1588
1974	3361	4441	1321
1975	4956	5475	1105
1976	3864	5657	1464
1977	4406	6294	1429
1978	4603	6576	1429
1979	2723	4279	1571
1980	3056	4266	1420

Source: Anon. (no date)

Genetic Improvement

Genetic improvement has followed a number of approaches.

Introduction

Introductions were grouped in three categories: white-seeded, pea or navy bean, and coloured-seeded.

White-seeded strains.

Many types of bean (*Phaseolus vulgaris* L.), similar to the *baladi* type, were introduced to attempt to identify materials with better yields of white, medium size seeds. Trials conducted at Hudeiba Research Station over a number of years (Table 2) consistently showed White Baladi to be superior in yield to introductions (Mutwakil, 1963-1967; Harran, 1969-1975). The introductions belonged to the Great Northern type of *fasulia* characterized by early maturity and large seeds. The superiority of the White Baladi was mainly manifested in pods/plant and seeds/ pod.

Table 2. Performance of Different Classes and Promising Strains of *Fasulia* (*Phaseolus vulgaris* L.) Under Irrigation at Hudeiba Research Station.

Cultivars	Yield (kg/ha)					
	65-66	66-67	67-68	69-70	70-71	Mean
White *Fasulia* Variety Trial						
Ro/2/1	1824	1214	1181	1956	2016	1638
GN. No. 31 (HRS 427)[a]	1558	1159	1118	1747	1764	1469
GN. No. 59 (HRS 426)	1476	906	766	1682	1776	1339
GN. No. 123 (HRS 428)	1553	989	720	1654	1613	1306
GN. No. 1140 (HRS 425)	1392	1010	547	1692	1128	1154
S.E.±	NR	50	104	60	98	
***Fasulia* Round Seeded (Pea Beans) Variety Trial**						
White Baladi	1834	1176	1354	1714	1987	1613
Sagenaw (415)	1567	684	854	1363	1336	1165
Michelite (416)	1126	730	977	1546	1476	1171
Sanilac (417)	806	715	823	1222	1159	945
Gratiot (418)	763	602	648	1109	1291	883
Seaway (419)	665	502	701	886	1234	798
S.E.±	77	82	NR	89	82	
***Fasulia* Colored-Seeded Variety Trial**						
White Baladi	2340	838	1308	2107	NT	1648
Red Mexican 34 (HRS 430)	2187	802	1387	2186	NT	1636
Red Mexican 35 (HRS 429)	2340	1034	1454	2196	NT	1756
Pinto (HRS 431)	1526	948	1339	2023	NT	1459
Red Kidney (HRS 420)	1020	516	566	1656	NT	940
S.E.±	71	·187	71	94	NT	

[a] GN Great Northern
NR = not reported
NT = not tested
Source: Mutwakil (1963-67), Harran (1969-75)

Recently, materials from CIAT considered to be adapted to western Asia and northern Africa were evaluated at Hudeiba Research Station (Salih 1987). They did not differ significantly from local matarials in seed yield and pods/plant but most had significantly larger seeds (Table 3).

Table 3. Haricot Bean Trial of Introductions from CIAT (1987).

Entries	Seed yield (kg/ha)	Pods/ plant	Weight of 100 seeds (g)
P_1	1510	9	19.6
CIAT 80	1398	8	36.0
HRS 545	1358	8	23.1
CIAT 85	1182	8	18.9
CIAT 20	1158	11	36.1
Basabeer	1152	8	18.4
CIAT 10	1077	10	39.5
Ro/2/1	1073	9	19.5
CIAT 18	1053	10	38.3
CIAT 42	951	9	24.5
CIAT 39	936	9	22.9
CIAT 22	916	10	35.8
CIAT 37	900	6	29.1
CIAT 23	900	9	38.5
CIAT 69	865	11	28.0
CIAT 38	857	8	30.8
CIAT 77	854	8	31.5
CIAT 75	853	10	38.0
CIAT 17	807	11	23.7
CIAT 63	787	12	38.7
CIAT 54	685	8	36.2
CIAT 24	673	12	34.3
CIAT 13	666	7	36.0
CIAT 14	647	8	38.5
CIAT 9	588	10	36.7
Mean	954	9	30.9
S.E.±	244.7	1.8	1.8

Pea or Navy Bean

Five pea bean cultivars with small, round, white seeds all produced significantly less yield than White Baladi (Table 2).

Coloured-seeded Group

Although white beans are preferred in the Sudan, some coloured-seeded types were included in the programme for possible export. They included the small red, mottled and dark red kidney types. Red Mexican 35 produced the best seed yields, significantly better than White Baladi in some tests (Table 2).

Landraces

Since only Red Mexican 35 among introductions produced equivalent yields to *baladi* types, selection was initiated within *baladi* to improve its tolerance to a blast-like disorder (subsequently found to be sodium toxicity injury), yield and salt tolerance (Mutwakil, 1963). Among the many lines selected, Ro/2/1 produced the best yields (Table 4). It outyielded Baladi by 49% with significantly more pods/plant and larger seed size (Mutwakil, 1968). The work culminated in the official release and adoption of Ro/2/1 as the standard *fasulia* cultivar in the northern region to replace the *baladi* type.

Table 4. Seed Yields, Pods/Plant and Seed Sizes of *Baladi* Selections in *Fasulia* (*Phaseolus vulgaris*) Variety Trial.

	Yield (kg/ha)		Pods/plant		Weight of 100 seeds (g)	
Entries	66-67	67-68	66-67	67-68	66-67	67-68
Ro/2/1	1469	1651	9.12	16.3	22.2	25.2
R1/5	1222	1582	8.37	15.94	20.7	19.7
R1/25	1068	1183	7.72	15.56	20.0	18.5
R1/7	1039	1486	8.00	18.76	17.9	19.4
Baladi	989	1063	7.55	15.50	18.0	16.9
R1/3	842	1222	7.82	19.3	19.1	17.6
R1/13	818	1238	6.90	14.38	16.8	17.7
R1/10	574	1049	5.82	14.42	17.5	16.8
R1/14	566	1044	5.77	15.10	16.9	17.8
S.E.±	100	199	0.53	2.31	0.96	1.48

Curly top resistance

Curly top disease causes heavy yield losses in phaseolus bean in some years. It is caused by a virus, transmitted by whitefly. Harran (1969) selected single plants from the local materials, Ro/2/1 and *baladi*, and found some families with a high degree of tolerance to curly top. Salih (1976) continued this work and the yields of nine selections from Ro/2/1 from 1972-78 are shown in Table 5. Line 8R gave the largest seed yield during the six years, out-yielding Red Mexican by 23% and Ro/2/1 by 18%.

Sodium Toxicity

Major reductions in yields of beans sown on warm days in sodic soils in the northern region of Sudan results from high plant mortality (Ishag and Ali, 1974) attributed to sodium toxicity injury, due to high temperatures causing rapid translocation of sodium to shoots. Ayoub and Ishag (1974) compared tolerance to sodic soils of snap bean and dry bean cultivars (Table 6). Late sown bean was little affected (Ayoub, 1974) but there were clear cultivar differences in the first and second sowing dates (Table 7). The study showed that beans tolerated excess sodium by suppressing sodium accumulation in stems and leaves.

Table 5. Seed Yields (kg/ha) of Nine *Fasulia* (*Phaseolus vulgaris*) Lines Resistant to Curly Top Disease from 1972 to 1978.

	Years						
Families	72-73	73-74	74-75	75-76	76-77	77-78	Mean
8R	1634	1848	1128	1992	1428	1260	1548
4B	1786	1512	1229	1913	1090	1102	1438
6B	1553	1656	1082	1951	1133	1262	1440
9B	1320	1394	1243	2083	1301	1646	1498
5B	1526	1661	1114	1834	1085	1090	1385
2B	1536	1714	1063	1894	1008	1303	1421
7R	1742	1260	1058	1795	1090	948	1315
1B	1373	1411	1020	1992	1166	1231	1366
3B	1270	1414	862	1860	1075	1303	1298
Ro/2/1	1297	1694	1082	1654	1135	1094	1318
Red Mexican	1339	1481	763	1354	1289	1385	1318
Mean	1488	1548	1058	1872	1162	1238	
S.E.±	129	168	156	89	96	192	

Source: Salih (1976-78)

Table 6. Survival of Some Bean Varieties in a Sodic Soil.

Entries	Survival (plants/m^2)	Death %
Top crop	0.2	99.1
Contender	0.4	97.8
Extender	0.5	96.8
Tender Green	0.7	96.2
Tender Crop	1.6	90.8
Ro/2/1	8.0	52.8
Red Mexican	13.2	22.1
Pinto	13.3	21.1
L.S.D. (P = 0.01)	2.16	NR
L.S.D. (P = 0.05)	1.56	NR

Source: Ayoub and Ishag (1974)

Regional Variety Trials

Regional variety trials were conducted to evaluate haricot bean lines in major bean producing areas and to study their adaptability with a view to identifying suitable cultivars for each locality. Every year poor yielding

Table 7. Inter-varietal Differences in Number of Plants/m^2 Survived as Affected by Sowing Date.

Entries	Sowing date 25 Sep	9 Oct	23 Oct	6 Nov	Mean
Contender	0.6	11.0	14.9	16.4	10.7
Ro/2/1	7.4	12.8	14.4	15.9	12.6
Pinto	10.4	13.9	14.9	17.0	14.1
Mean	6.1	12.6	14.7	16.4	
L.S.D. (P = 0.01)		2.74			2.37
L.S.D. (P = 0.05)		2.04			1.76

Source: Ayoub (1974)

lines were replaced by superior ones selected from local genotypes and introductions for comparison with Ro/2/1 and Baladi (Salih, 1981-88). The largest average seed yield was produced by Red Mexican, which outyielded Ro/2/1 by 19% (Table 8). The poorest average seed yield was produced by Baladi. At Hudeiba and Zeidab, locally selected materials tended to be better than introductions but this was reversed at Shendi, where HRS 545 produced 23% more yield than Ro/2/1. In seasons which were not conducive to high productivity, HRS 545 was the best yielder and appears to tolerate unfavourable conditions, so could be recommended for release in Shendi. At Basabeer, seed yields were good and Ro/2/1 out yielded all introductions except Red Mexican and HRS 560. All introductions had larger seeds than local genotypes.

To extend the cultivation of dry bean to new areas south of Khartoum, Hassan (1969-75) initiated a variety trial study at Sennar, Gezira, Shambat and Shendi. The heaviest yield was obtained at Shendi (Table 9). Yields at Gezira and Sennar were less than at Shendi, but economically feasible due to cheap water supply and available land. None of the introductions yielded better than local *baladi* materials.

Processing Quality of Dry Beans

Dry bean is important for processing at a time when other vegetables are not available. The suitability of the various dry bean cultivars of different regions for processing was investigated (Hassan and Mubarak, 1978). Seed size and proportion of non-soakers were substantially affected by location and cultivar.

Conclusions

Dry bean (*Phaseolus vulgaris* L.) contributes substantially to the diet of the people of Sudan and still ranks high as a cheap source of protein in

Table 8. Seed Yields and Seed Sizes of Entries in Haricot Bean Regional Variety Trials.

Entries	Hudeiba		Shendi		Zeidab	Bassabeer	Mean		
	Seed yield (kg/ha)	Wt. of 100 seeds (g)	Seed yield (kg/ha)	Wt. of 100 seeds (g)	Seed Yield (kg/ha)	Seed yield (kg/ha)	Seed yield (kg/ha)	Wt. of 100 seeds (g)	Yield % of Ro/1/2
Red Mexican	2264	22.2	1935	22.4	2137	2894	2308	22.3	119
HRS 560	1849	24.0	1863	25.0	1920	2485	2029	24.5	104
Basabeer	1923	20.8	1580	NR	2194	2227	1981	20.8	102
Ro/2/1	1796	20.2	1557	20.9	2212	2220	1946	20.6	100
HRS 518	1699	24.8	1888	25.5	1908	2162	1914	25.2	98
BR	1945	19.8	1577	18.6	2135	1973	1908	19.2	98
HRS 519	1706	24.1	1968	NR	1856	1995	1881	24.1	97
P_1	1805	18.6	1631	18.1	2036	2039	1878	18.4	97
HRS 516	1672	24.3	1851	23.6	1894	2078	1874	24.0	96
HRS 531	1591	23.1	1943	25.4	1768	2085	1847	24.3	95
HRS 545	1674	23.3	1912	24.9	1831	1839	1814	24.1	93
Baladi	1566	17.6	1191	19.9	1787	1826	1593	18.8	82
Mean	1791	21.9	1737	22.4	1973	2150	1914	22.2	

NR = not reported

Table 9. Seed Yields (kg/ha) of *Fasulia* Cultivars (*Phaseolus vulgaris*) - means of three seasons.

	Location				
	Sennar	Gezira	Shambat[a]	Shendi	Mean
Dark Red Kidney	524	778	1606	1218	1032
Great Northern	867	1173	1556	2132	1432
White Kidney	909	1005	1408	1811	1283
Baladi S	1129	1408	1408	2221	1542
Pinto	862	1334	1359	2208	1441
White Bean	1008	1141	1161	2161	1368
Light Red Kidney	627	746	840	1275	872
Perry Marrow	793	773	790	1944	1075
Baladi	1099	1149	NT	2292	1513
Mean	869	1056	1266	1918	1277

[a] One season only; NT = not tested
Source: Hassan (1970-72).

comparison with animal protein. It is also a good source of cash for farmers and can fetch a high price in nearby Arab countries. Besides its food value and high returns to farmers, bean plays an important role in many agricultural systems because of its nitrogen fixing abilities thus saving considerable energy for the manufacture of fertilizers. Production, area and yields have declined in the last ten years due to inferior cultivars, most farmers being unaware of the improved cultivars developed at Hudeiba Research Station. The plant propagation section responsible for production and distribution of seeds of cultivars released by the crop variety release committee is only able to provide a fraction of certified seed requirement to farmers due to lack of facilities.

Future expansion of dry bean production is likely to be in Karu soil or sodic soils away from the alluvial river silt and in the central heavy clays of Sudan with cheap water and available land. Thus selection and breeding to obtain cultivars tolerant to excess sodium, curly top disease and high temperature should be accelerated.

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Breeding Bean for Resistance to Diseases

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Abstract

Seven bean (Phaseolus vulgaris L.) lines contrasting in disease resistance and agronomic characters were crossed in a diallel. The parents, F_1s, F_2s and F_3s were evaluated and selected in glasshouse and field for resistance to rust, Uromyces phaseoli (Reben) Wint, anthracnose (Colletotrichum lindemuthianum), angular leaf spot (Phaeoisariopsis griseola), halo blight (Pseudomonas phaseolicola) and bean common mosaic virus (BCMV). F_4s and F_5s were evaluated in the field only. Several F_4 and F_5 lines combining resistance to three or more diseases, acceptable seed characteristics and good yield potential were selected from nine crosses.

Introduction

Common bean (*Phaseolus vulgaris* L.) is the most important pulse crop in Kenya, second only to maize in importance (Njuguna *et al.*, 1981). The seeds have relatively high amounts of lysine, trytophane and methionine which are often inadequate in cereal based diets. Yields of bean in farmers' fields in Kenya (estimated at 150 kg/ha in a pure stand and 375 kg/ha in association) are less than in other major bean producing regions of the world (Londono *et al.*, 1981). Diseases and pests are considered the main limiting factors to bean production in Kenya (Njuguna *et al.*, 1981). The main diseases and pests and losses associated with them are listed in Table 1.

Early efforts in bean improvement in Kenya focused on germplasm collection and its evaluation for resistance to diseases and pests at the National Horticultural Research Centre (NHRC), Thika and the University of Nairobi in the early 1970s and from 1980, at the National Dryland Farming Research Centre, Katumani. This work culminated in the release by the Grain Legume Project at the NHRC of several bean varieties such as GLP-2, (Rose Coco), GLP-24, (Canadian Wonder), GLP-X-92 (Mwitemania) and GLP-1004 (Mwezi Moja).

Although these cultivars had desirable seed types, yield and other attributes, they were susceptible to some diseases. For example, GLP-X-92, a popular variety, has excellent resistance to halo blight but is very susceptible to rust. Some landraces and accessions were resistant to several diseases but had undesirable seed characteristics, for example, NB-123, a local landrace collected from Kirinyaga, which was unacceptable because of its small, black seeds (Mukunya and Keya, 1975, 1977; Mwangi, 1980). Little work has been done to combine the disease resistance of these landraces with acceptable seed type and good adaptation of other accessions.

Table 1. Major Bean Diseases and Pests in Kenya, Their Causal Agents, Mode of Transmission and Economic Importance.

Disease/pest	Causal agent	Mode of transmission	Economic importance/ yield loss
Fungal diseases			
Rust	*Uromyces phaseoli*	air	I, 18-100%
Anthracnose	*Colletotrichum lindemuthianum*	seed	I, up to 100%
Angular leaf spot	*Phaeoisariopsis griseola*	air	I/M
Bacterial diseases			
Halo blight	*Pseudomonas phaseolicola*	seed	I, 42% (Mukunya and Keya, 1975)
Common blight	*Xanthomonas phaseoli*	seed	I, NR
Fuscous blight	*Xanthomonas phaseoli* var. *fuscans*	seed	I, NR
Virus diseases			
Bean common mosaic	BCMV	seed	I, 53-68, 27-63% (Omunyin, 1979)
Insect pests			
Beanfly	*Ophiomyia phaseoli*	NA	I, NR
Aphids	*Aphis fabae*	NA	I, NR
Bollworm	*Heliothis armigera*	NA	I, NR
Bean beetle	*Acanthoscelides obtactus*	NA	I, NR
Nematodes			
Root knot nematodes	*Meloidogyne javarica* *M. incognita*	soil	I, NR

I = important; M = moderately important,
NR = yield loss data not reported; NA = not applicable
Source: Njuguna *et al.* (1981)

The purpose of this work was to hybridize bean cultivars with contrasting traits and select for recombinants with resistance to rust, anthracnose, BCMV, angular leaf spot and halo blight.

Materials and Methods

Materials

The characteristics of the seven bean cultivars used for this study are shown in Table 2.

Table 2. Characteristics of Seven Bean Lines Used in Crosses.

Parent	Growth habit	Days to 50% flower	Days to maturity	Grain yield (kg/ha)	Weight of 100 seeds (g)	Disease reaction						
						Rust	Anth	ALS	HB	CBB	BCMV	RR
GLP-2	Ia	49	91	1828	52	S	R	S	S		R	
GLP-288	Ia	47	96	1201	43	S		S			MR	
GLP-X-92	IIIa	48	92	1472	39	S	S	MR	R		S	
GLP-24	IIa	52	100	1662	34	S	R	R	MR		S	
M535	IIa	54	95	1732	49	R	R	R				
L226-10	Ia	56	104	1907	18	R		R			R	R
NB-123	IVa	52	97	1722	20	R	R		R			

GLP-2 (Rose Coco), GLP-288 (Rose Coco type), GLP-X-92 (Mwitemania) and GLP-24 (Canadian Wonder) are cultivars released by the NHRC in the late 1970s. They have medium to large seeds, good culinary qualities and are well adapted to medium and high potential bean growing areas. They are resistant to some diseases and susceptible to others. M535 was derived from irradiated Canadian Wonder seeds. It has large seeds, yields better than GLP-24 (Kimani, 1988) and is resistant to anthracnose, rust and angular leaf spot.

NB-123, indigenous in Kenya, has small black seeds and is resistant to all common races of bean anthracnose (Mwangi, 1986), halo blight and rust (Mukunya and Keya, 1977). L226-10 was developed and released cooperatively by the ARS-USDA, Michigan State University and the University of Puerto Rico. It is resistant to rust, BCMV, angular leaf spot and several root rots. However, the seeds are white and small. All seven parental lines have above average yield potential.

Methods

The seven parents were intercrossed using a modified Buishand (1956) hooking method in a glasshouse at Kabete Field Station in 1986 and 1987 to constitute a 7 x 7 complete diallel (Tumwesigye, 1988). Selected F_2 plants were advanced to the F_3 and further generations on the basis of disease reaction.

BCMV strain 510 was obtained from the Pathology Section of the NHRC (Omunyin, 1979). Inoculum was prepared by macerating 22 day-old diseased plants in 0.01M potassium phosphate buffer at pH 7.3 in a 1:1 ratio of tissue:buffer. The crude extract was diluted 1:10 in water. Ten-day old glasshouse-raised plants were dusted with 500/600 mesh carborundum and inoculated mechanically at temperatures of $25 \pm 5^{o}C$.

Inoculum suspension for *Pseudomonas phaseolicola* was prepared in distilled water from 48 hr old cultures grown in yeast dextrose calcium carbonate agar (YDCA) medium. The suspensions were adjusted using a 'Spectronic 20' spectrophotometer (Bausch and Lamb Co) at 600 nm to a concentration of about 5×10^7 colony forming units (CFU) per ml water. The abaxial surface of primary and first trifoliolate leaves of 12-day old plants were sprayed with bacterial suspensions using a De Vilbiss No. 15 atomizer attached to a compressed airline at 15 p.s.i., until water soaking appeared. Distilled water was used as a control. Inoculated plants were kept in a glasshouse at 22°C.

Colletotrichum lindemuthianum was isolated from diseased pods, leaves and stems and cultured on potato dextrose agar (PDA) at 20°C for three to five days. Single spores were isolated and sub-cultured on PDA and then on bean pod enriched nutrient agar plates (phosphate buffer - 0.1 M, pH 7.2) and incubated at 20°C for five to seven days. Spores were dislodged from the media and placed in 200 ml sterile water, filtered through cheesecloth and the suspension adjusted to a concentration of 1.0×10^6 spores/ml using a haemocytometer. Primary and first trifoliolate leaves of 12 days old plants were inoculated with the suspension using a Bayer atomizer (Bayer E.A. Ltd.), covered with moistened polythene bags for 48 hours and kept in the glasshouse at about 25°C.

Disease Assessment

Pots containing parent, F_1, F_2 and F_3 plants were arranged in a randomized complete block design with four replications in the glasshouse. Each pot had two plants and four pots constituted a plot for parents and F_1s. There were 8 pots per plot for F_2 and F_3 plants.

In the field, spacing was 50 cm between rows and 10 cm between plants. Plot size was 8 m^2 for parents and 10 m^2 for F_2 and F_3 populations. F_1 plants were sown in two, 3 m rows. The experimental design was a RCB with four replications. Disease reactions were assessed 35 and 40 days after inoculation in the glasshouse and just prior to flowering in the field.

A five category disease severity scale was used:

1. No symptoms.

2. Few isolated lesions ($\leq$2% of leaf affected).

3. Many small lesions (3-10% of leaf affected).

4. Few to many large lesions scattered over leaf blade (11-25% leaf area affected).

5. Many large, coalesced lesions accompanied by chlorosis, necrosis and/or dead leaves or plants ($\geq$26% of leaf area affected).

Classes 1-2 were considered resistant; 3, moderately resistant; 4, tolerant; and 5, susceptible. Rust and angular leaf spot assessments were carried out in the field under natural epiphytotics. F_4 and F_5 lines were also assessed for disease reaction and other traits only in the field.

Results and Discussion

Of 2,139 crosses made in 1986, 1,799 were successful - a success rate of 84.1%. In 1987, 1,800 crosses were made, of which 1,400 were successful - a success rate of 77.9%. The mean success rate for the two years was 80.1%

which was considerably more than the 30-40% reported by Buishand (1956) and comparable to 70-80% recorded at Max Plank Institute at Voldagen. The greater success rate was attributed to a modification of the hooking method of Buishand (1956), which allows more pollen to remain in contact with the stigma. This enables fertilization of more ovules and a greater number (4-7) of hybrid seeds per pod. Secondly environmental conditions necessary for successful pollination (Buishand, 1956; Bliss, 1980) were strictly provided for during the crossing period.

Crossing between large (GLP-288, GLP-24, M535) and small-seeded (L226-10 and NB-123) lines produced deformed F_1 seeds. Nearly all germinated but the first trifoliolate leaves of seedlings failed to unfold, became chlorotic, necrotic, stunted and dehisced, roots degenerated and plants died 20-40 days after sowing. All the F_1s with NB-123 as one of the parents died except two plants of the cross GLP-288 x NB-123. A few plants of crosses with L226-10 survived to produce F_2 seeds. F_2 populations of these crosses segregated 9:7 (dwarf: normal). There were no reciprocal differences in expression of this abnormal development. The contrasting development of parents and F_1 plants and the distinct segregation into phenotypic classes in F_2 populations confirmed that the condition was inherited (Tumwesigye, 1988) and caused by the segregation of the two complementary dominant genes first described by York and Dickson (1975).

Selection for Resistance

F_2 plants rated resistant or moderately resistant to three or more of the five diseases (anthracnose, angular leaf spot, rust, halo blight and BCMV) in field and glasshouse were selected and grown to produce F_3 seeds. F_3 plants were raised at Kabete in glasshouse and field. Only glasshouse plants were artificially inoculated, except for BCMV. BCMV strain 510 was used for inoculating both field and glasshouse grown F_3 plants. Disease severity was generally more in the glasshouse than in the field. However, due to many years of continuous cropping of bean at Kabete Field Station and very favourable weather conditions in 1989 for disease development, disease incidence was generally high and susceptible plants were identifiable and discarded. Selected F_3 families were advanced to F_4 and F_5. Results of selection in F_4 and F_5 are shown in Table 3.

Of the initial 42 crosses (including reciprocals) five, involving NB-123 and GLP-288, GLP-24 and M535 were lost due to F_1 mortality. F_4 and F_5 lines from nine crosses were finally selected based on their disease reactions.

Twenty five F_5 lines were selected from the cross GLP-288 x M535. They were resistant to three or more diseases and moderately resistant to others. Due to the high incidence of common bacterial blight and beanflies during the long and short rainy seasons of 1989, severity was assessed. For beanflies, plants were rated on the basis of mortality (less than 2% resistant, 3-10% moderate, 11-25% tolerant, over 25% susceptible) and number of pupae/larvae in stems. The lines had fairly large seeds and yield levels generally above their parents (Tables 2 and 3).

Nineteen F_4 lines were selected from the cross L226-10 x NB-123. The lines were resistant or moderately resistant to BCMV, rust, angular leaf spot, halo blight and beanflies. They were also moderately resistant to common

Table 3. Seed Weight, Grain Yield and Disease Reactions of Selected Crosses at Kabete, During Long and Short Rains, 1989-90.

Cross	Generation	Number of lines selected	Weight of 100 seeds (g)		Seed yield (kg/ha)		Disease reactions						
			Mean	Range	Mean	Range	Rust	Anth	ALS	HB	CBB	BCMV	BF
GLP-288 x M535	F_5	26	48.3±7.1	35.2-67.3	1687±543.7	673-2842	HR	HR	HR	HR		HR	HR
L226-10 x NB-123	F_4	19	20.5±2.3	16.3-28.7	1017±442.9	525-2649	MR/R		MR/R	MR/R	HR	MR/R	MR/R
M535 x L226-10	F_4	10	32.2±7.6	19.7-50.6	1441±771.7	646-3423	R	R	R	R	MR	R	MR
GLP-2 x M535	F_5	15	46.2±14.8	18.3-57.1	1631±373.1	1235-2327	MR/R	MR/R	MR/R	MR/R	MR/R	MR/R	
GLP-2 x NB-123	F_5	5	34.0±5.5	25.2-42.8	1174±300.7	706-1927	R	R		MR		R	R[1]
GLP-X-92 x GLP-288	F_5	6	53.5±9.3	54.0-65.1	1612±377.7	1039-2217	R[2]		MR[3]		MR	MR	
GLP-2 x L226-10[4]	F_4		33.9±10.1	21.4-53.6	517±345.7	193-1407	R[5]	R	R	R		R	MR
GLP-X-92 x NB-123	F_4	6	34.5±6.1	23.2-43.5	705±212.5	442-1054	R[6]	R	R	R			
GLP-288 x GLP-24	F_5	19	52.3±9.6	17.3-65.6	2018±465.9	170-3663	MR		MR/R		MR/R	MR/R	

[1] four lines; [2] two lines; [3] four lines;
[4] three lines resistant to all five diseases; [5] six lines;
[6] three lines
HR = highly resistant; R = resistant; MR = moderately resistant

blight, as expected since both parents were important sources of resistance to all these diseases. However, most lines had black, white or grey seeds like their parents. Their mean size (20.5 g/100 seeds) was also comparable to their parents. All had seeds weighing less than 30 g/100.

Ten F_4 lines from the cross M535 x L226-10 showed resistance to BCMV, halo blight, anthracnose, rust, angular leaf spot and moderate resistance to beanflies and common blight. Their seed sizes were intermediate between their parents although some segregants had large seeds and their yield varied from 646 to 3,423 kg/ha.

Five F_5 lines were selected from the cross GLP-2 x NB-123. They were all resistant to rust, BCMV and anthracnose and moderately resistant to halo blight. Four were also resistant to beanflies. They had medium sized seeds and a yield range of 706 to 1,927 kg/ha.

Lines selected from the cross GLP-2 x M535 had large seeds, like their parents, and a mean yield of 1,631 kg/ha. Three lines (K21/23, K21/29A and K21/45A) had yields over 2,000 kg/ha. They were resistant or moderately resistant to BCMV, anthracnose, common blight, rust and angular leaf spot.

Of the six lines selected from the cross GLP-X-92 x GLP-288, only two were resistant to rust and four were tolerant to angular leaf spot. However, they showed resistance to BCMV, anthracnose, common blight and beanflies. These lines had the largest seeds of all crosses selected and larger than their parents.

Three of the 18 lines selected from GLP-2 x L226-10 showed resistance to all diseases assessed. These were K26/19, K26/35B and K26/47B. Only six of the 18 lines were resistant to rust.

Three lines (K30/1, K30/4D and K30/41) from the cross GLP-X-92 x NB-123 were resistant to all six diseases and beanflies. They also had seeds intermediate in size between their parents.

The results indicate that it is possible to generate genotypes that are resistant to major bean diseases in Kenya and in eastern Africa in general. This is important in view of the large grain losses caused by these diseases

(Hubbeling, 1973). Although there are many alternative methods of controlling bean diseases, resistance is the most cost efficient for resource poor farmers. Selection emphasized non-race specific resistance (horizontal) without excluding possible race-specific (vertical) resistance. This may be useful because most causal agents of these diseases exist in many alternative forms (Mwangi, 1986; Mukunya and Keya, 1975). The lines identified in F_4 and F_5 showed a wide range of seed sizes and colours. Further selection work will emphasize seed sizes and colours that appeal to consumers. Generally, small black and white seeds are not preferred in Kenya. Selected lines will be evaluated across locations and seasons for their reactions to diseases and their yield potential.

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Breeding Bean (Phaseolus vulgaris L.) Adapted to Intercropping

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Abstract

Seventy-three hybrid populations of bean (Phaseolus vulgaris L.) were developed at Thika. Commencing at F_2, F_3 or BC_1, seeds from each population were separated into two portions. In subsequent segregating generations, each portion of seed was advanced and selected in pure stand or in association with maize at two locations in Kenya. In order to characterize the ideal bean genotype for cultivation in association with maize, the performances of genotype groups were compared with respect to yield, yield components and developmental plant characteristics. Genotype by cropping system interactions were addressed. In a series of four experiments, the correlation coefficients (r = 0.24, -0.15, 0.17 and 0.26) between the yields of genotypes in monoculture and in association with maize were small and did not differ significantly from zero. Genotypes selected in association with maize produced better grain yields in association than those selected in pure stand. Early flowering, short duration, short stature and profuse branching were consistent features of genotypes selected in association with maize.

Introduction

The cultivation of bean in association with other crop species is a primary characteristic of bean production in eastern Africa and Latin America. Bean is intercropped with potato, banana, groundnut and even plantation crops such as coffee.

Allard and Bradshaw (1964) consider association with a cereal to be a primary characteristic of traditional bean production systems. Mian (1977) reports that American Indians raised bean in association with corn for many years before the birth of Christ. Santa-Cecilia and Vieira (1978) reported that 70 per cent of the bean crop in Brazil is produced in associated systems, primarily with maize. In Kenya, 69 per cent of bean production is in association with other crops (Schonherr and Mbugua 1976). Bean production in other Africa countries is no less dominated by association with other crops. Osiru (1980), states that 75-90 per cent of bean production in Uganda is in association.

Traditional cropping systems have utilized landraces of crop species selected by the farmer in his specific microclimate and system. Modern plant breeders on the other hand have selected and evaluated genotypes in pure stand, assuming such genotypes perform as well in association.

Although the conscious selection of genotypes specifically adapted to complex cropping systems has received low priority in plant breeding programs, the need for genotypes for associated cropping is recognized (Finlay, 1976; Hamblin, *et al.*, 1976; Muigai and van Rheenen, 1982), based on the contrasting environments between pure stands and associations rather than on any factual data.

The need to verify the presumption that superior genotypes of bean selected in pure stand will also be optimum in intercropping is of paramount importance. Equally important, is to show empirically that specific bean genotypes are required for specific cropping systems, if the former is not the case.

This work explored the nature of differences among the characteristics of bean genotypes selected in pure stand or in association with maize when grown in both cropping systems. With the assumption that genotypes must, by the nature of the environments under which they were selected, be quite diverse, the occurrence of genotype x cropping system interactions was investigated.

Materials and Methods

Seventy three hybrid populations of beans were developed at the National Horticultural Research Centre, Thika by crossing adapted popular local bean types with lines resistant to anthracnose or Bean Common Mosaic Virus. The populations were handled as families through either F_1, F_2 or one backcross, prior to pedigree selection at two climatically different sites, Machakos (National Dryland Farming Research Centre), with marginal rainfall, and Embu (Eastern Agricultural Research Centre), with medium rainfall.

Seeds of each population were randomly separated into two parts for selection in pure stand or in association with maize.

The selection blocks were arranged in a systematic design. During the first two selection cycles, control plots were included to assess field variability. As seed quantities increased and the number of selected entries decreased, it became possible to have two replicates for the fourth cycle and three replicates during the fifth and sixth selection cycles.

In monoculture, bean was grown in rows 50 cm apart with 10 cm between plants along the rows, to give a population of 200 thousand plants/ha, and diammonium phosphate was banded in the furrows at sowing at the rate of 200 kg/ha. In association with maize, bean was in rows 25 cm apart and 15 cm intra-row, to give 178,778 plants/ha. and maize was 75 cm between and 30 cm within rows, for a population of 44,444 plants/ha. At sowing, diammonium phosphate was banded at 100 kg/ha to bean and maize received triple superphosphate at the rate of 150 kg/ha. Maize was side-dressed with calcium ammonium nitrate at knee height.

During each cycle, single plants or progeny rows were selected on two occasions, at podding stage and at physiological maturity. Selection criteria included general plant vigour, freedom from diseases and grain yield. At Machakos, where rainfall is marginal, earliness of maturity was also emphasized.

To compare bean genotypes emanating from the two cropping systems, split-plot experiments were conducted: at Thika in 1981 and 1982; and at Embu and Machakos in 1982. Environmental characteristics of the three locations are shown in Table 1.

Table 1. Environmental Characteristics of the Selection Locations.

Location	Province	Climatic zone	Soil classification	Annual rainfall (mm)	E_t (mm)	Mean temperature (°C)	Coordinates S	E
NHRC	Central	II	Rhodic Ferralsol	1020	1214	19.4	0°59'	37°04'
EARC	Eastern	II	Dystric Nitosol	1238	1207	20.7	0°30	37°07'
NDFRC	Eastern	IV	Chronic Luvisol	718	1193	19.5	1°35'	37°14'

NHRC = National Horticultural Research Centre, Thika;
EARC = Eastern Agricultural Research Centre, Embu;
NDFRC = National Dryland Farming Reseach Centre, Machakos;
Climatic zones II = dry sub-humid to semi-arid, IV = semi-arid;
Source: Siberius and Muchena (1977)

In pure stand, subplots consisted of five bean rows each measuring 3.6 m in length. The net plot was the central 3.6 m^2. In association with maize, five double rows of bean were grown between five maize rows. Net plots for bean were the central 3.6 m^2, while the middle three rows of 2.4 m were the net plots for maize.

Developmental and yield characteristics were measured on ten plant samples, randomly selected from the net plots. In one experiment, freshly opened flowers on a sample of three plants randomly selected at the start of flowering were counted over a duration of 21 days. Grain yield was determined on the entire net plot and a random sample of one hundred seeds was taken to determine seed size.

Analysis of variance was performed to determine the contributions of genotypes, selection systems and test environments to the total variation of each character recorded. Correlation coefficients were computed between the yields of genotypes in pure stand and in association with maize.

Results and Discussion

There were significant interactions between genotypes and cropping systems in three out of four trials for duration and in one trial for grain yield, days to flowering, height to attachment of highest pod, plant height and number of branches (Tables 2 and 3). Duration of flowering and number of flowers per plant showed significant genotype by cropping system interactions in the one trial where they were recorded. Correlations between the yields of genotypes in pure stand and in association with maize were in all cases low and not significantly different from zero (r = 0.24, -0.15, 017 and 0.26). Maize performance was not affected differentially by bean genotypes.

Based on their observations of significant genotype by cropping system interactions for various characters in soybean, Semu and Jana (1975), Finlay (1976) and Makena and Doto (1980) advocated development of specific genotypes for specific cropping systems.

Table 2. Means of Yields and Yield Related Characteristics of Bean Genotypes Selected in Pure Stand and in Association with Maize in the same Two Cropping Systems in Trials in Four Environments in Kenya.

Character	Selection system	Thika 1981 PS	Thika 1981 ASS	Thika 1982 PS	Thika 1982 ASS	Embu 1982 PS	Embu 1982 ASS	Machakos 1982 PS	Machakos 1982 ASS
Yield	PS	491	522	655	632	674	627	93	101
(g/plot)	ASS	275**	311	367	315	390	397	87	92
Productive	PS	8.8	8.8	8.6	8.5	10.0	9.9	3.2	3.0
pods/plant	ASS	5.9*	6.9	6.4	6.4	7.4	7.5	2.8	3.0
Seeds/pod	PS	3.9	4.0	3.7	3.9	4.0	3.9	3.2	3.1
	ASS	3.8**	3.8	3.5	3.5	3.7**	3.5	3.2	3.3
Unproductive	PS	3.0	3.3	3.1	3.6	3.5	4.1	2.3	1.6
pods/plant	ASS	3.3	3.2	2.3	2.2	3.2**	3.3	3.1**	2.4
Weight of 100	PS	29.9	31.7	39.8	37.4	39.3	38.6	NR	NR
seeds (g)	ASS	30.3	30.9	36.0**	32.6	41.5	41.5	NR	NR
Flowers/plant	PS	28.3	30.9	NR	NR	NR	NR	NR	NR
	ASS	22.3*	24.8	NR	NR	NR	NR	NR	NR

PS = pure stand; ASS = associated with maize; NR = not recorded;
* and ** interactions between selection and testing systems significant at P<0.05 and <0.01, respectively

Reported correlation coefficients between the yields of bean genotypes in pure stand and in association have been mainly large and positive (CIAT, 1978; Francis *et al.*, 1978; Francis and Sanders, 1978). May and Misangu (1980) contended that genotypes developed in pure stand did not give significant differential responses in different environments. The genotypes studied here did seem capable of differential responses perhaps due to the selection procedures used in their development.

Genotypes selected in association with maize exhibited significantly shorter times to flowering and to maturity, reduced plant height and more profuse branching in all trials. Clark and Shibles (1979) suggested the early onset of reproductive growth as a trait adapted to associated cropping. Osiru (1980) suggested early maturity and erect, determinate growth habit as traits for associated cropping. However, within the non-climbing growth habits (Types I, II and III), growth habit was reported to be of no consequence to adaptation to cropping system (Anon., 1976).

No disease and pest incidence of any practical importance occurred in these trials. Intercropping has been reported to naturally protect the bean component from pests and diseases (Mukiibi, 1976; Shoyinka, 1976; Keswani *et* *al.*, 1980; van Rheenen *et al.*, 1981). When selecting for associated cropping, therefore, it may well be desirable to sacrifice disease resistance for greater potential yields.

Table 3. Means of Developmental Characteristics of Bean Genotypes Selected in Pure Stand and in Association with Maize in the same Two Cropping Systems in Trials in Four Environments in Kenya.

		Environment							
		Thika 1981		Thika 1982		Embu 1982		Machakos 1982	
Character	Selection system	PS	ASS	PS	ASS	PS	ASS	PS	ASS
Days to 50% flower	PS	44.7	41.1	41.4	40.5	38.6	36.8	42.2	43.5
	ASS	45.7**	41.6	41.4**	39.9	38.6**	37.4	43.9**	41.7
Days to maturity	PS	91.1	88.2	85.0	85.0	86.3	85.9	90.9	87.2
	ASS	88.3*	86.0	88.3*	87.1	89.9**	87.7	86.9**	85.0
Branches/ plant	PS	3.8	4.2	2.5	2.6	1.8	2.0	-	-
	ASS	3.3**	4.1	2.0	2.2	1.7**	1.8	-	-
Lowest pod attachment[a]	PS	19.9	20.2	26.6	25.4	25.2	24.2	18.7	18.0
	ASS	21.2	20.1	20.7*	19.9	28.7**	27.2	21.9	20.9
Highest pod attachment[a]	PS	85.7	41.9	47.9	44.4	46.3	44.1	25.3	25.1
	ASS	45.5**	41.3	32.0**	31.0	53.3**	47.7	31.2	31.9
Plant height[a]	PS	76.6	69.1	64.4	54.2	32.1	55.3	35.0	36.1
	ASS	83.7**	71.6	42.0**	38.8	73.9**	61.6	46.0	51.1
Duration of flowering	PS	18.4	19.2	NR	NR	NR	NR	NR	NR
	ASS	16.5**	18.2	NR	NR	NR	NR	NR	NR
Flowers/ plant	PS	28.3	30.9	NR	NR	NR	NR	NR	NR
	ASS	22.3*	24.8	NR	NR	NR	NR	NR	NR

PS = pure stand; ASS = associated with maize; NR = not recorded;
* and ** interactions between selection and testing systems significant at P<0.05 and <0.01, respectively; [a] cm

Conclusions

The selection of bean in pure stand and in association, resulted in genotypes with contrasting plant features.

Short duration was one adaptive feature of bean for association. Early onset and completion of the reproductive phase would ensure that yield in the bean is determined prior to the commencement of competition from the maize.

The study indicated a short-statured, profusely-branched bean to be suited to associated cropping. Short stature appears contrary to requirements for large total dry matter production to guarantee high grain yield. However, short stature may reduce above ground competition. Moreover, profuse branching can contribute towards a better display of photosynthetic area. As wide variation for branching evidently exists, maximizing this character should compensate for any dry matter production foregone by short stature. Strong stems may also be desirable.

Within the suggested plant framework, grain yield may be maximized through increased number of nodes, racemes and pods per plant.

Summary

Bean populations were advanced and selection carried out in pure stand or in association with maize. Selected genotypes were used to study adaptive features of bean to associated cropping to assess the need for development of separate genotypes for specific cropping systems.

Among genotypic features pertinent to the ideal intercropping genotype, early flowering and short duration were most clearly indicated from the study.

Profuse branching within a short plant stature was also shown to be a positive architectural characteristic for a bean genotype suitable for associated cropping.

The hypothesis that specific bean genotypes are required for specific cropping systems was supported by the results of the study.

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Genetic Improvement of Common Bean for Resistance to the Necrosis-Inducing Strains of BCMV

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Abstract

Bean common mosaic virus (BCMV) is an important cause of disease in Phaseolus vulgaris in Africa. It is transmitted naturally in seeds and by aphids. It is also readily mechanically transmitted, which facilitates screening for resistance. Several strains of the virus have been identified. Both dominant (I) and recessive resistance genes (bc) have been identified in the host. The virus induces various types of symptom on susceptible plants and these are described. Mosaic occurs only in genotypes lacking the dominant I gene. The virus induces black root only in genotypes carrying the I gene. A local lesion reaction can occur in certain genotypes - pinpoint, in the presence of the I gene protected by recessive genes - and ring-shaped, with recessive genes alone. A set of differential cultivars aids the identification of strains of BCMV. The two genotypes, II+bc-2² and bc-3 alone, confer effective resistance to existing strains of BCMV. The backcross breeding system being used at CIAT to transfer these combinations into different adapted backgrounds is described. Thirty advanced lines, with the combinations, coded MCM and MCR, are already available in the VEF.

Introduction

Bean common mosaic virus (BCMV) is considered to be the most important seed-borne virus of common bean (*Phaseolus vulgaris* L.) of the world. Field infection may reach 100% and yield losses ranging from 6 to 98% have been reported. However, the severity of yield loss depends upon the cultivar and the time of infection (Galvez and Morales, 1989). In Africa, BCMV is considered to be a major disease problem and the principal viral disease affecting bean production (CIAT, 1981).

The host range for BCMV has been reported to be fairly broad, including many tropical and subtropical leguminous crops, pastures and shrubs. However, under natural field conditions, BCMV is primarily restricted to *Phaseolus* spp., particularly *P. vulgaris* (Galvez and Morales, 1989). The virus particles collected from crude sap of BCMV infected plants can be readily seen with the electron microscope. They are flexuous filaments about 750 nm long and 15 nm wide. BCMV is classified in the potyvirus group (Drijfhout, 1978).

Symptomatology

Bean common mosaic virus induces two general types of symptoms depending upon the cultivars, the time of infection, the strain of the virus and the environmental conditions.

Common mosaic

Mosaic symptoms appear in systemically infected cultivars causing mottling, curling, stunting and malformation of primary leaves. Typical common mosaic symptoms consist of well-defined dark green areas of foliar tissue against a lighter green background of the rest of the affected leaf lamina (Morales, 1989). Infected leaves may also appear narrower and longer than unaffected leaves.

Black root

Systemic necrosis (black root) symptoms may occur in cultivars possessing the hypersensitive, monogenic-dominant I gene upon infection by necrosis-inducing strains of BCMV. This necrotic reaction begins in the youngest trifoliolate leaves and spreads rapidly down through the entire vascular system of the plant. Characteristic reddish brown to black streaks appear on the leaves, stems, roots and pods. Plants affected by black root initially exhibit wilting and later die.

Transmission

The most important epidemiological factor responsible for the worldwide distribution of BCMV is its ability to infect the seed embryo and thus be transmitted through seed. On average there is 10 to 30% BCMV transmission to seed from infected plants. However, the incidence of seed transmission may vary considerably depending on the bean genotype infected and the BCMV strain. Plants infected after flowering usually will produce a reduced proportion of infected seed.

BCMV is also transmitted by several aphid species such as *Myzus persicae* and *Aphis fabae*. Usually virus acquisition and transmission by the vector occur within 30 to 60 seconds. In the tropics, infected seed and plants of susceptible bean cultivars serve as sources of primary inoculum for BCMV and aphids are responsible for the secondary transmission of the virus (Galvez and Morales, 1989).

BCMV is also readily transmitted by manual or mechanical means. At CIAT, breeding lines and segregating populations emerging from BCMV resistance programs are all inoculated manually with different strains of the virus depending on the resistance genes being incorporated.

Responses of Bean Cultivars to BCMV

Four basic plant responses may be expected in bean genotypes inoculated with BCMV (Morales, 1989).

Mosaic

This symptom results from systemic infection of a susceptible cultivar by BCMV and indicates that the dominant I gene is absent. However, strain-specific recessive genes which confer resistance to selected BCMV strains may be present.

Systemic or Local Necrosis

The occurrence of necrosis in a genotype indicates the presence of the dominant I gene. The necrotic reaction may be localized (restricted vein necrosis) or systemic (black root). These hypersensitive I gene genotypes may or may not possess BCMV strain-specific recessive genes.

Local Lesions

Two types of local lesions occur depending on whether or not the genotype carries the I gene. The occurrence of pin-point local lesions indicates the presence of the I gene, protected by a recessive gene. The induction of ring-shaped local lesions indicates that the genotype possesses recessive genes, but that the dominant I gene is absent.

Immunity

The absence of mosaic or necrosis symptoms in BCMV inoculated plants (immune response) depends on the strains used and the resistance gene possessed by the genotype. One recessive gene, bc-3, gives complete resistance to all known strains of the virus identified to date.

Control by Plant Resistance

Plant resistance to BCMV was discovered nearly 60 years ago in the cultivar Robust, and attributed to a single recessive gene. Subsequently, another type of resistance, the hypersensitive dominant I gene, was identified in Corbett Refugee and also found to be present in several tropical land races. Because it was very effective against BCMV in many bean producing areas of the world, this gene was widely incorporated into commercial cultivars.

However, other strains of the virus were identified which caused black root systemic necrosis in cultivars possessing the I gene. Cultivars with resistance to these strains were found and the genes possessed by them were described by Drifjhout (1978).

The BCMV resistance genes now being used by plant breeders are present in the following cultivars, plus others not listed (Morales, 1989):

Gene	Dominance	Cultivars
I	Dominant	Corbett Refugee
bc-1	Recessive	Imuna
$bc\text{-}1^2$	Recessive	Redlands Greenleaf B
bc-2	Recessive	Michelite
$bc\text{-}2^2$	Recessive	GN 31
bc-3	Recessive	IVT 7214
bc-u[a]	Recessive	

[a] a strain unspecific gene present in Imuna, Redlands Greenleaf B, Michelite, GN 31 and other cultivars and necessary for complete action of their strain specific recessive genes when the I gene is recessive.

The genes bc-1 and bc-1^2, as well as bc-2 and bc-2^2, are considered to be allelic and so both cannot be combined in a single homozygous genotype (Drijfhout, 1978).

To identify strains of BCMV and study the genetics of resistance, a set of differential cultivars has been formed (Table 1) (Drijfhout, 1978). Cultivars in subset A are those that do not possess the dominant I gene. In this group, mosaic is the predominant symptom recorded in inoculation tests. However, when certain combinations of recessive resistance genes are present in a genotype, two other symptoms are expressed: ring-shaped lesions in the GN 31 group, when inoculated with all strains except NL4 (which causes mosaic symptoms); and in the IVT 7214 group, where there is complete immunity due to the presence of the bc-3 gene.

Table 1. Genetic Interactions Between Bean Common Mosaic Virus Strains and Selected *Phaseolus vulgaris* Cultivars (adapted from Drijfhout, 1978).

Differential Cultivars	Resistance genes	Type	Florida	NY15	NL4	NL8	NL3	NL5	Symptoms
A. Cultivars with recessive alleles (i^+i^+) of the necrosis gene									
Dubbele Witte	I^+	M	M	M	M	M	M	M	Mosaic
Imuna	I^+ bc-u bc-1	-	M	M	M	-	M	M	Mosaic
Redlands G. B	I^+ bc-u bc-1^2	-	M	-	M	-	M	M	Mosaic
Sanilac	I^+ bc-u bc-2	-	-	M	-	M	M	M	Mosaic
Pinto 114	I^+ bc-u bc-1 bc-2	-	-	M	-	-	M	M	Mosaic
G.N. 31	I^+ bc-u bc-1^2 bc-2^2	-	-	-	M	-	-	-	Ring-shaped lesions
IVT 7214	I^+ bc-u bc-2 bc-3	-	-	-	-	-	-	-	Immunity (bc-3)
B. Cultivars with dominant alleles (II) of the necrosis gene									
Widusa	I	-	-	-	-	N	N	N	Systemic necrosis
Top Crop	I bc-1	-	-	-	-	-	N	N	Systemic necrosis
Amanda	I bc-1^2	-	-	-	-	-	-	N	Systemic necrosis
IVT 7233	I (bc-1^2) bc-2^2	-	-	-	-	-	-	-	Pin-point lesions

In B (Table 1) are cultivars which possess the dominant I gene. When inoculated with the necrosis-inducing strains (NL8, NL3 and NL5), systemic necrosis is observed. With the cultivar group IVT 7233, containing two recessive genes, only pin-point lesions are produced by these strains. The soft or mosaic-inducing strains (Type, Florida, NY15 and NL4) do not cause symptoms in the I gene cultivars.

Breeding for BCMV Resistance for Africa

Studies are under way to fully characterize the BCMV strains present throughout bean growing areas of Africa. Preliminary results indicate that the necrosis-inducing strain, NL3, predominates in central Africa. although other strains are present, as well as in other regions of Africa.

Whenever the NL3 strain is present, the I gene alone is ineffective. Indeed, it may be preferable to have cultivars that are fully susceptible to BCMV (like the majority of bean land races) than to grow cultivars possessing only the I gene, as systemic necrosis is much more likely to kill plants than systemic mosaic.

Breeding for resistance to the necrosis-inducing strains of BCMV began in 1978 as a collaborative project between IVT-Wageningen and CIAT. The purpose of this project was to produce bean lines adapted to the tropics with multiple BCMV resistance genes. The project ran from 1978 to 1987 and four complete backcrosses were made among a variety of genotypes to combine the dominant I gene with the recessive bc-u, bc-1^2, bc-2^2 and bc-3 genes. Because the bc-3 gene confers complete immunity, test crosses were made in the F_2 generations of all crosses to identify the presence of the other genes.

For practical breeding purposes, however, it is not necessary to combine all resistance genes. When CIAT began sole management of the breeding project, only two types of resistance continued in use: II+bc-2^2 and bc-3 alone. The II+bc-2^2 combination can readily be identified in segregating populations inoculated with NL4 and NL3 by the characteristic pin-point lesions. The bc-3 gene alone is frequently used now since it confers complete immunity. The bc-3 gene also has another advantage in that, unlike the I gene, it does not appear to possess unfavorable linkages with seed coat color.

The breeding scheme used at CIAT for the bc-3 gene is outlined in Figure 1. A backcross program is being used to incorporate the gene into commercial African cultivars and elite breeding lines. At present 30 advanced lines containing II+bc-2^2 (coded MCM) and 24 lines containing the bc-3 gene (coded MCR) are available in the VEF nurseries provided by CIAT. The overall objective of this program is to incorporate BCMV into all major grain classes of beans for either subsequent release as cultivars or use as parents in resistance breeding programs.

Figure 1. Backcross Breeding to Incorporate Resistance to Mosaic and Necrosis-Inducing Strains of BCMV Present in Africa.

Susceptible cultivar x MCR 2502 (bc-3)

↓

F_1 (recessive genes cannot be identified in F_1)

↓

F_2 (30-50 F2 plants inoculated with a mixture of NL4 and NL3 strains, transplant immune plants and backcross to commercial variety)

↓

F_1BC1 (recessive genes not identifiable)

↓

F_2BC1 (30-50 seeds with seed type approaching that of commercial cultivar, plants inoculated with NL4 and NL3 (bc-3), immune plants transplanted and backcrossed to commercial variety)

↓

F_1BC2 (recessive genes not identifiable)

↓

F_2BC2 (30-50 seeds with commercial seed types inoculated with NL4 and NL3, immune plants (bc-3) transplanted

↓

F_3BC2 (5-10 seeds/plant inoculated NL4 and NL3, immune types (bc-3) transplanted

↓

F_4BC2 (field tests, selection for agronomic types)

↓

F_5BC2 (field tests, uniform progeny bulked)

↓

VEF (MCR lines - bc-3)

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CIAT's Role in Bean Genetic Improvement in Eastern Africa

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Abstract

Phaseolus bean is an important food crop in eastern Africa. The development of heavier yielding cultivars can contribute to meeting the urgently required improvements in productivity, due to increasing demand stemming from population growth and decreasing land availability. For many years CIAT has made available to national programmes, in trials and nurseries, a wide range of genetic variation that is a prerequisite for achieving progress in breeding programmes. National programmes in Uganda and Ethiopia (and in other countries in Africa) have successfully exploited this variation to release improved cultivars and recent results indicate that further yield improvements may be expected. Resistant sources to prevalent and important diseases and pests have also been identified and are being incorporated into existing cultivars. The evolution of a regional research network has permitted the sharing of responsibilities among national programmes to tackle problems of regional importance through regional sub-projects. Inter-regional linkages have strengthened, most particularly in germplasm exchange via the dissemination of elite breeding material, solicited from all national programmes, in a pan-African trial. Data from this trial and environmental parameters are being used to develop more effective strategies for bean improvement in Africa.

Introduction

The importance of *Phaseolus vulgaris* as a food crop in eastern Africa is well documented and the wealth of local names given to distinctive cultivars is evidence of their long establishment (Allen *et al.*, 1989). However, over the period 1970-89, only Uganda and Kenya showed significant and positive growth rates in production, largely explained by an increase in area under production in Kenya and in productivity in Uganda (Grisley, 1990). And in all countries except Kenya, population growth rate markedly exceeded growth in production.

Land scarcity will eventually limit further expansion of production area and increased demand from population growth and Governments' desire of an excess for export will have to be met by improvements in productivity. Breeding can contribute to such improvements by developing new cultivars with a heavier yield stemming from better resistance/tolerance to one or more of the prevalent biotic and abiotic factors constraining yield, rather than use of inputs unavailable to resource-poor farmers.

Utilization of CIAT Germplasm

Genetic variation is a prerequisite for character improvement in any breeding programme. Such variation may be locally available in landraces, originating from earlier introductions, and has been successfully exploited to release new cultivars, such as White Haricot, in Uganda in 1989 (Sengooba, 1989) and Brown Speckled and Red Wolaita in Ethiopia some 15 years ago. The genetic base of such landraces is, however, often too narrow for sustained improvements, necessitating the procurement of additional genetic variation either through hybidization programmes or, perhaps initially more easily, by introduction from outside agencies. CIAT has for many years made available various forms of trials and nurseries comprised of advanced breeding lines, disease and insect resistant sources and segregating populations that provide national programmes with a wide range of genetic variation for evaluation.

Yield Improvement

In Uganda and Ethiopia, the breeding programmes are structured to permit an orderly flow of genetic material through an extensive and well defined sequence of trials (Table 1), with progressively fewer lines tested at a greater number of sites. Since 1986 an increasing number of lines have been introduced into both countries from CIAT, culminating with the release in 1989 of two new cultivars in Uganda and four in Ethiopia.

Table 1. Evaluation Sequences for Breeding Materials in Uganda and Ethiopia.

	Uganda			Ethiopia		
		Numbers			Numbers	
Testing stage	Trial name	Sites	Test lines	Trial name	Sites	Test lines
1	Screening Nursery[a]	1	500-800	Nursery I[a]	4	800-1,000
2	Preliminary	1-3	250-500	Nursery II	3-4	70-73
3	Intermediate	4	100-138	Pre-National Variety Trial	6-7	40-45
4	Advanced	8-10	20-23	National Variety Trial	9-10	25-30

[a] non-replicated.

Currently, 500 to 1,000 lines are introduced annually and, after preliminary screening, selected lines are evaluated in a sequence of replicated trials. Recent results from both countries show that substantial yield increases over the original cultivars (K20 and Brown Speckled) and more importantly over the new cultivars (Rubona 5, White Haricot and Roba 1) are being achieved at the intermediate and advanced testing stages (Tables 2, 3 and 4). Improvements over the white pea bean cultivar, Awash 1, are noticeably smaller.

Table 2. Mean Yield Across Locations of the Five Heaviest Yielding Lines, Relative to the Control Cultivars, in Intermediate Yield Trials (IYT) in Uganda in 1990 and in Nursery II Trials (NII) in Ethiopia in 1989.

Uganda				Ethiopia			
Trial	Control cultivar	Control yield (kg/ha)	Line yield (%)[b]	Trial	Control cultivar	Line yield (kg/ha)	Line yield (%)[b]
IYT-LS	K20	737	134-165	NII-LS	Brown Speckled	3097	119-162
	Rubona 5	822	120-148				
	White Haricot	1148	86-106				
IYT-SS1	K20	833	121-136	NII-MS	Roba 1	2414	186-193
	Rubona 5	551	140-157				
	White Haricot	1041	137-149				
IYT-SS2	K20	1000	136-147	NII-WPB	Awash 1	3310	96-107
	Rubona 5	966	141-153				
	White Haricot	1135	112-121				

SS, MS and LS = small, medium and large seeded, respectively; WPB = white pea bean; IYTs, NII-MS and NII-WPB at 4 locations, NII-LS at 3 locations; [a] range expressed as % of control yield

Table 3. Mean Yield Across Sites, Expressed as a % of Control Cultivar Yield, of Entries Common to the National Variety Trials (NVT) in Ethiopia in 1988 and 1989.

	Large-seeded NVT			Medium-seeded NVT			White Pea Bean NVT		
	Entries	1988[a]	1989[a]	Entries	1988[a]	1989[b]	Entries	1988[a]	1989[b]
Entry yields (% of control)	A 262	169	137	A 265	113	119	BAT 1281	101	99
	A 410	153	131	A 445	116	124	PAN 135	102	108
	A 483	143	108	A 442	114	113	BAT 1198	98	115
	Diacol Calima	134	111	BAT 85	92	100	BAT 338-1C	100	107
				A 62	92	84			
Control yields (kg/ha)	Brown Speckled	1365		Roba 7	2053	2600	Awash 1	2206	2443

[a] 7 locations; [b] 8 locations

Although not all of the across-site increase of up to 69% over the control cultivars can be expected at the farm level, the wide adoption of the best lines could nevertheless contribute to meaningful increases in production. Furthermore, it would seem reasonable to infer that such increases, using CIAT derived materials, could be achieved in other countries

Table 4. Mean Yield Across Sites, kg/ha and as % of Control Cultivar Yield, of Entries Common to Advanced Yield Trials in Uganda in 1989 and 1990.

	kg/ha		% of K20, R5 and WH					
			1989			1990		
Entries	1989	1990	K20	R5	WH	K20	R5	WH
GLP 582	1136	928[a]	135	156	115	113	111	89
GLP 585	883	1116	105	121	90	136	133	107
DOR 372	847	1124	101	116	86	137	134	108
DOR 375	955	1351	114	131	97	165	161	129
BAT 448	866	1056	103	119	88	129	126	101
BAT 1220	912	1203	109	125	93	147	144	115
Suchitan	1035	1235	123	142	105	151	147	118
Controls								
K20	840	820						
Rubona (R5)	728	838						
White Haricot (WH)	984	1492						

[a] seed yield adversely affected by reduced stand in 1990

in eastern Africa, where such material has been little utilized, and that further advances can be derived from future introductions.

Disease Resistance

Estimates of the relative importance of bean diseases in Africa have been obtained chiefly from studies conducted on research stations using artificial inoculation with crop loss estimates ranging from 4 to 92% for anthracnose, 8 to 25% for angular leaf spot, 11 to 100% for rust, 43 to 78% for scab and 14 to 78% for bean common mosaic virus (Allen *et al.*, 1989). Other important diseases in Africa are common bacterial blight, halo blight and ascochyta blight.

Studies have demonstrated that the chemical control of disease can produce substantial yield improvements. In Rwanda, diagnostic on-farm trials recorded yield increases of 400-1,000 kg/ha from the chemical control of fungal and bacterial pathogens (Allen *et al.*, 1989). In Uganda, a 72% increase in yield stemmed respectively from the control of angular leaf spot by mancozeb and common bacterial blight by cupric carbonate (Sengooba, 1989). In Ethiopia, substantial yield responses were evident from the application of Plantovax to control rust (Habtu, personal communication). In spite of such increases, the cost of chemicals is beyond the reach of most small farmers and disease control at the farm level can be best achieved from the development and diffusion of disease resistant/tolerant cultivars. Recognizing this need

CIAT has devoted considerable resources over the years to identifying and incorporating resistant sources into breeding lines, which have been distributed in disease nurseries for evaluation by national programmes for resistance to prevalent pathogens.

Since 1988, the national programme in Uganda has made considerable progress in identifying resistant sources in the international disease nurseries from CIAT (Table 5). From 44 to 64% of the lines in the international CBB, halo blight and rust nurseries proved resistant at test sites in Uganda, whereas much smaller percentages of resistant lines were evident in the international anthracnose, angular leaf spot and ascochyta blight nurseries. In the latter two, however, many lines showed better levels of resistance than locally available materials. Lines from CIAT with resistance to the necrotic strains of BCMV, which predominate in Uganda, are presently being screened and an international BCMV nursery is now being distributed.

The best sources of resistance to common bacterial blight and ascochyta blight are currently being incorporated into local landraces and commercial cultivars in Uganda. In the longer term, confirmed sources of resistance to other diseases will be utilized to develop multiple disease resistant cultivars.

Insect Resistance

The principal insect pests of beans in eastern Africa and reported estimates of resulting crop losses are: beanflies (30-100%), pod borers (15-25%), aphids (90%, Uganda only) and bruchids (weight loss in storage of up to 40%). Other minor pests include foliage beetles, leaf hoppers, flower thrips, pod sucking bugs and spider mites.

Recent work has concentrated on developing and screening for sources of resistance to beanflies (*Ophiomyia* spp.) and the bruchid weevil *Zabrotes subfasciatus*. From three seasons of screening in Ethiopia of over 1200 germplasm accessions from CIAT, representing the total range of variation in the germplasm collection, five lines were identified as having excellent

Table 5. Evaluation of International Disease Nurseries from CIAT in Uganda from 1986 to 1989.

Nurseries			Year of	Number of lines	
Disease	Year	Location	test	Tested	Resistant
Common bacterial blight	1986	Kawanda	1988	99	51[a]
Common bacterial blight	1987	Bukalasa	1988	100	64
Halo blight	1987	Kachwekano	1988	96	60
Ascochyta (phoma) blight (bush)	1989	Kachwekano	1989	13	0(13)[b]
Ascochyta (phoma) blight (climbing)	1989	Kachwekano	1989	12	1(12)
Angular leaf spot	1988	Kawanda	1989	100	1(56)
Anthracnose	1988	Kawanda	1989	69	12
Rust	1988	Kawanda	1989	100	44

[a] 45 of these lines showed similar resistance in Ethiopia and Colombia
[b] number of lines more resistant than the resistant control in parentheses

seedling survival under conditions of attack by beanflies. Since then, screening of further introductions has identified additional sources of resistance, which are being distributed in the Beanfly Reconfirmatory Nursery.

Among the different methods of bruchid control CIAT has emphasized the search for and development of bean materials with resistance to their attack. After no adequate levels of resistance were detected in more than eight thousand cultivated bean lines, the search was extended to wild bean accessions of Mexican origin, among which were found materials with a high level of resistance to *Z. subfasciatus*. Consequent work identified the resistance factor to be a new protein which was called arcelin and which has since been incorporated into a range of breeding lines. A trial in Uganda in 1990 confirmed the resistance against a local strain of Z. subfasciatus., with the hoped inference that it will be effective against strains in other African countries.

Regional Activities

Recognizing the constraints of limited manpower and resources in national programmes, CIAT has promoted the formation of a regional research network in eastern Africa. This provides an opportunity for joint planning by national programmes of research priorities and activities, training and exchange of germplasm. This has led to the evolution of a number regional sub-projects (RSPs) that allow the division of responsibilities among national programmes in tackling problems of regional importance (Table 6).

Table 6. Regional Sub-projects of the Regional Programme on Beans in Eastern Africa, 1990-91.

Regional sub-project	Lead Country	Cooperating Countries
Rust	Ethiopia	Kenya, Uganda, Rwanda, Mauritius
Common bacterial blight	Uganda	Ethiopia, Rwanda
Ascochyta (Phoma) blight	Uganda	Burundi, Rwanda
Bean common mosaic virus	Uganda	Ethiopia, Kenya, Sudan
Beanflies	Kenya	Ethiopia, Uganda
Bruchids	Somalia	Uganda
Seed multiplication	Ethiopia	All countries

The seed multiplication RSP in Ethiopia, together with input from CIAT, handles the multiplication of promising breeding lines, submitted by national breeders, for inclusion in an Eastern African Zonal Bean Evaluation Nursery (EAZBEN) and Trial (EAZBYT), with the first of these to be distributed in 1991. In 1990, the more mature RSPs on CBB, ascochyta blight and rust each distributed regional nurseries, comprising CIAT derived and local resistant/tolerant entries. In addition the first two RSPs in Uganda are providing segregating populations for local selection from crosses requested by other national programmes. Surveys conducted by the BCMV RSP has identified the endemic strains in Uganda and Ethiopia and will assist in the development of a BCMV regional nursery of resistant lines. Beanfly and bruchid RSPs have recently been initiated to determine species distribution, assess control methods and identify sources of resistance; a regional beanfly nursery of resistant/tolerant lines has already been distributed.

Inter-Regional Activities

A similar range of RSPs has developed in the other two CIAT regional programmes in the Great Lakes area and southern Africa, and linkages via monitoring tours, meetings and workshops provide for inter-regional dissemination and discussion of research findings. Germplasm exchange has progressed further with the first and second African Bean Yield and Adaptation Nurseries (AFBYANs), comprised of entries solicited from all national programmes, already distributed in Africa. In future, the promotion of superior lines from the three sets of regional breeding trials to the AFBYAN will provide a dynamic system for the pan-African distribution of elite breeding material.

Although substantial yield improvements over existing cultivars have been made in many countries in Africa using CIAT derived material, ways are being examined to allow more selective targeting of genetic material to different agro-ecozones in Africa. Smithson (1990) described the use of environmental parameters to construct a similarity index to identify similarities between production areas in Africa and test locations used by CIAT in Colombia to evaluate bean materials. This, and a similar analysis within Africa, complemented by data on genotypic behaviour from the AFBYANs, should assist in evolving more effective strategies for the flow of better adapted bean material to and within Africa.

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Experiences in On-Farm Research (OFR) with Bean Cultivars in Laikipia District of Kenya

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Abstract

On-farm trials of three bean cultivars, Rose Coco (local) and Kat B1 and Kat MM for three seasons (second seasons of 1988 and 1989 and first season of 1989) are described. The trials were conducted around three stations in Laikipia District, which has a cool, dry climate, in Rift Valley Province of Kenya. Farmer involvement was emphasized, in order to obtain a true reading of performance on-farm. Kat MM produced the best grain yield across seasons, stations and overall. Weather and management conditions were very variable and it was difficult to interpret the variation in yields across trials. Further tests are necessary to confirm the suitability of the new lines for cultivation in the area.

Introduction

Laikipia is one of 13 districts in the Rift Valley Province of the Republic of Kenya. It is situated between longitudes 36°10' and 37°3'E and latitudes 0°17' and 0°45'N and covers an an area of 9,723 km^2 with an altitude range of 1,800 to 2,600 masl, sloping gently lower northwards. The district lies on the leeward side of Mt. Kenya forming the arid and semi-arid highlands of the west and north-west of the mountain.

Experiencing a dry and cool climate, Laikipia forms part of the unique dryland region in the country with limited water sources for rainfed farming. In view of the fragile physical environment, realistic development needs to address itself to optimal water storage in the soil, proper cultivation methods, crop selection, reclamation of swamps and possibilities of irrigated farming (Anon, 1989). Whereas the National Dryland Farming Research Center (NDFRC-Katumani) serves the hot and dry areas of the country, a research center to cater for cold and dry areas has yet to be established and Laikipia could be ideal considering its contrasting physical characteristics.

The target area for the OFR is Matanya which is representative of south western parts of the district. It is situated about 20 km SW of Nanyuki (capital of Laikipia District) on latitude 00°03'12"S and longitude 36°57'06"E at an altitude of 1,842 masl. It is characterised by dark clay soils with vertic properties (phaeozems) and slopes of 3 to 5%. The average annual rainfall is 700 mm and bimodal, allowing two growing seasons a year. Farmers, immigrating mainly into Laikipia from higher potential areas, tend to be resource poor and lack knowledge of dry land farming and become beset by numerous problems. These include: small farm size (2-4 acres); unreliable, inadequate and unevenly distributed rainfall; low temperatures (frequent frosts); little available capital; and lack of recommended crops and appropriate accompanying cultivation methods for the area.

The farmers' traditional crops/cultivars and cultivation methods are not easily adapted to the cold and dry conditions. The end result is recurrent crop failure, which calls for plant breeding and/or crop selection for cold and drought resistance. Irrigation development as an option during dry periods has not been studied to determine its potential in the area and district as a whole. However, papers presented by various authors in soil and water conservation seminars imply that there are many water sources in the area but with poor recharge, which does not favour irrigated agriculture.

The on-farm research on bean, which is the subject of discussion in this paper, is essentially verification of on-station trials carried out on bean for three consecutive years (1986-1987) on an experimental plot in the target area. Based on the results of these trials, the cultivars Kat B1, Kat MM and Rose Coco were recommended for OFR in which farmers actively collaborate in the selection of adapted and acceptable bean cultivars for the area. An informal survey indicated that the major crops in the area are maize, irish potato and bean, all grown in association. The OFR aims at introducing new improved bean cultivars into existing farming systems without creating new problems for farmers.

On-farm verification trials of bean cultivars in Matanya have been conducted now for three consecutive seasons starting with the second season of 1988. The second seasons of 1988 and 1989 were unusually wet throughout the growing periods (Tables 1 and 2), so the results may not represent the cold and dry conditions of the area. The first season of 1989 was wet during the vegetative phase of the bean crop (March-April) but experienced a dry spell from flowering to harvest (May-June). These unpredictable weather conditions complicate interpretation of results. The data collected include rainfall amount, temperature, phenological phase, incidences of pest and diseases and crop yields and duration (days from sowing to physiological maturity).

Objectives of OFR in Matanya

The objectives of OFR in Laikipia are to: involve farmers in the selection of adapted bean cultivars through verification of the performance and acceptability of Kat B1 and Kat MM under farmers' circumstances and field management; and recommend the promising cultivars for extension services in Matanya and other areas of similar agroecological conditions.

Methodology

Sowing of the trials has always been preceded by discussions on production constraints and farmers' priorities followed by selection of farmers for the trials. The field extension staff lay out the plots together with the farmers. The farmers are then given seeds of the cultivars and advised to sow at the same time and in the same way they sow their own bean crop. Farmers themselves carry out all field operations from land clearing to harvesting. Key operations like sowing and harvesting are witnessed by field extension agents. The extension agents undertake observations and data collection including taking measurements like weight and moisture content of grain.

Table 1. Ten-Day Means of Rainfall and Temperature at Three Stations in Matanya during the Second Season of 1988.

		Station 1				Station 2				Station 3			
		Temperature				Temperature				Temperature			
Month	Dates	Max-imum	Min-imum	Mean	Rain-fall (mm)	Max-imum	Min-imum	Mean	Rain-fall (mm)	Max-imum	Min-imum	Mean	Rain-fall (mm)
October	1-10	36.0	11.0	20.8	24.3	NR	NR	NR	NR	29.0	10.0	19.7	0.0
	11-20	31.5	9.2	21.0	0.0	NR	NR	NR	NR	32.0	6.0	19.1	3.1
	21-31	32.0	10.0	20.1	31.2	NR	NR	NR	NR	30.0	7.0	18.2	80.5
November	1-10	31.0	12.0	19.6	35.3	23.0	14.0	17.8	20.9	26.0	9.0	18.9	9.8
	11-20	31.0	10.0	19.0	18.1	21.0	13.0	16.0	14.5	28.0	9.0	17.9	5.0
	21-30	31.0	9.0	18.7	5.1	20.0	12.0	16.6	15.5	29.0	7.0	17.4	27.3
December	1-10	31.0	9.0	19.0	3.2	24.0	13.0	17.4	68.6	29.0	6.0	17.9	25.0
	11-20	32.0	9.0	19.7	41.7	20.0	11.0	16.3	83.1	28.0	6.0	19.0	73.3
	21-31	27.0	9.0	18.7	21.3	24.0	10.0	17.6	41.1	29.0	9.0	17.8	40.2
January	1-10	29.0	9.0	18.3	0.0	22.0	11.0	16.8	0.0	29.0	7.0	18.9	1.3
	11-20	28.0	9.0	18.2	18.6	23.0	12.0	16.8	50.8	29.0	7.0	18.8	37.9
	21-31	39.0	8.5	17.5	0.0	24.0	12.0	17.6	0.0	30.0	6.0	18.8	0.0
February	1-10	31.5	8.5	19.3	20.3	23.0	12.0	17.3	51.9	31.0	6.0	18.7	35.4
	11-20	31.0	7.5	18.2	4.9	23.0	12.0	17.0	11.5	30.0	5.0	17.1	7.5
	21-29	29.0	7.0	18.2	1.5	25.0	10.0	16.8	0.0	31.0	2.0	17.1	0.0
Mean/total		30.7	9.2	19.1	285.5	22.7	11.8	17.0	358.0	29.3	6.6	18.3	346.3

NR = not recorded; Station 1, Edward Wang-odu; Station 2, Joyce Wanjira; Station 3, Moses Waigwa

The trials are supervised by the LRDP Agronomist and Agricultural Officer, who also formulate the programme. Supervision involves guidance and encouragement of the field extension agents and assessment of farmers reactions and opinions during execution and after harvesting. The supervisory team processes and analyzes the data and creates an atmosphere of discussion and conclusions before subsequent trials. In this way, OFR on beans has been a joint venture between agricultural staff and farmers in a partnership atmosphere.

Selection of Entries

Nineteen bean cultivars and lines were evaluated in on-station trials at an experimental plot in Matanya from 1985 for five consecutive seasons in collaboration with the Ministry of Agriculture (MoA) and NDFRC-Katumani (Zublin, 1988). The 19 entries included 9 local cultivars (Rose Coco, Canadian Wonder, Mario, Mwitemania, Njikariathi, Mwezi Moja, Brown/Pink, Black/White, and New Local) and 10 lines from NDFRC (Kat B1, Kat MM, Kat B9, Kat B2, PB6, PB13, B2X, ADTA, B and C).

Data collected included phenological phases, yields, incidences of pests and diseases, rainfall, temperatures and general field performance.

Based on grain yield, duration, cold tolerance and resistance to pests and diseases, Kat B1 and Kat MM were recommended for verification against the local cultivar Rose Coco on-farm and Mwezi Moja, Njikariathi and Kat B9 to undergo further observations in the experimental plot.

Table 2. Monthly Means of Rainfall and Temperature at Three Stations in Matanya in 1989.

Month	Station 1				Station 2				Station 3			
	Temperature			Rain-fall (mm)	Temperature			Rain-fall (mm)	Temperature			Rain-fall (mm)
	Max-imum	Min-imum	Mean		Max-imum	Min-imum	Mean		Max-imum	Min-imum	Mean	
January	18.0	8.5	29.0	48.6	17.1	11.0	24.0	50.8	18.8	6.0	30.0	39.2
February	18.6	7.0	31.5	26.7	17.0	10.0	25.0	63.4	17.6	2.0	31.0	42.9
March	21.2	8.5	34.5	78.9	18.1	11.0	26.0	108.8	19.5	4.0	34.0	0.0
April	NR	NR	NR	73.5	17.8	12.0	32.0	113.8	19.6	8.0	32.0	26.3
May	26.6	11.0	31.0	30.7	17.8	13.0	24.0	20.1	19.3	10.0	32.0	89.7
June	20.3	9.0	31.0	8.9	17.6	11.0	24.0	0.0	19.5	8.0	31.0	0.0
July	18.9	10.0	31.0	116.1	NR	NR	NR	NR	18.8	8.0	31.0	79.4
August	20.1	25.0	13.0	37.3	18.5	10.0	31.0	38.0	18.9	9.0	32.0	45.4
September	20.6	24.5	15.5	34.6	19.6	10.0	30.0	46.2	19.1	9.0	30.0	54.8
October	20.4	25.5	14.0	110.4	20.4	10.0	30.0	81.9	20.0	13.0	30.0	82.5
November	20.4	11.0	31.0	104.3	19.6	10.0	29.0	341.3	18.6	12.0	25.0	205.5
December	19.5	8.0	32.0	102.1	20.0	8.0	32.0	108.3	19.5	10.0	29.0	58.9
Mean/total	18.2	12.3	24.5	772.1	17.0	9.7	25.6	973.1	19.1	8.3	30.6	724.6

NR = not recorded

Selection of Farmers

Selection of farmers was undertaken in August-September 1988 by LRDP in collaboration with Laikipia Research Programme (LRP). An informal survey was conducted by the supervisory team together with field extension agents with the help of a simple questionnaire in which 130 farmers were identified for OFR. The criteria to select a target of 20 farmers included: low to medium wealth; total farm size 2-4 acres; not more than 8 livestock units (LU) (1 LU = 1 cow = 5 sheep or goats); at least 6 years of cultivation; at least 2 persons working on the farm; at least 0.5 acres under cultivated crops; interest in OFR; and luvic verto phaeozems - P3-P4 soil classification.

Twenty eight farmers were finally selected. A meeting of the selected farmers was convened and chaired by the area chief. Here, the farmers were informed of their roles and the purpose of the trials. The same farmers have been retained throughout, except eight who were dropped due to various reasons such as farm insecurity, identified during implementation. Of the remaining 20, half have been considered for OFR on mulching as a water conservation method leaving 10 farmers for the cultivar trials.

Planning and Experimental Design

Possible ways of incorporating the OFR trials in farmers' fields without inconvenience and the plan and design of the experiments were agreed at a meeting chaired by the District Agricultural Officer and attended by the LRDP Agronomist, the Divisional Agricultural Extension and District Crop Development Officers and an LRDP Agricultural Officer (secretary).

The experimental design was a single replicate of the three cultivars on each farm with a plot size of 5 x 6 m. A detailed instruction sheet accompanied by data collection sheets was prepared and given to the field extension agents. This design was used for the 2nd season of 1988 and 1st season of 1989. The participants of an OFR seminar held in Nanyuki in May 1989 visited the trials and held discussions including experimental designs. A follow-up of the seminar discussions by the MoA, LRDP and NDFRC-Katumani led, in the 2nd season of 1989, to the adoption of two replicates per farm separated by a 1 m alley and sowing the bean in 6 alternate rows with maize, 45 cm apart and 5 m long.

Field Operations

Extension agents laid out the plots in conjunction with farmers. All fields operations were carried out by farmers according to their traditional practices, ruling out extension input. This was a deliberate move to asses how the cultivars would perform under farmers' circumstances and field management. Observation and data collection were by extension agents under the supervision of the LRDP Agronomist and Agricultural Officer. Thus implementation was a joint venture between officers and farmers themselves in partnership.

Land preparation was by hand, using various implements including, hoes, plain jembes, pangas and fork jembes.

Sowing, observed by field staff, was also by hand - dibbling 2-3 seeds per hill. Since both farmers and field staff are new to the area, which is semi-arid with erratic rainfall, it was difficult to establish sowing dates. Farmers sow maize any time they receive rain. Bean was sown before the time set by MoA and unlike maize is grown twice each year.

Spacing varied depending on the farmers cropping pattern/plant arrangement and varied from 25 x 25 cm to 40 x 60 cm in the first two seasons, adjusted to 90 x 15 cm in the third season in association with maize.

Neither manure nor inorganic fertilizers were applied. Manure is available but not used and the purchase of inorganic fertilizers is too risky considering the high frequency of crop failure. Neither were pesticides applied.

The trials were weeded by hand, using mainly *pangas*, by both family and hired labour, depending on the ability of the farmer. Each trial was weeded twice on average but the timing differed from farm to farm, some being weeded before flowering, others during flowering and yet others (for a second time) after flowering.

Harvesting was handled by extension agents and farmers together. Mature plants were uprooted by hand. The pods were picked and seeds removed. The grains were weighed on the spot and moisture content determined immediately. The entire produce was left with the farmer.

Results and Analysis

The main parameters and elements considered in the analysis of results included grain yield (kg/ha), growth duration (days from sowing to physiological maturity), plant population, rainfall, temperature and moisture content. To a less extent, weed control, cropping patterns, farmers reactions and opinions were also considered.

The OFTs were carried out under farmers' circumstances involving at least 20 smallholders. There was no managerial recommendation for the trials extended to the farmers. However, numerous factors, including variations in cropping patterns, plant population and field management in general, influenced the performance of trials resulting in a wide range of yields. This variation was not unexpected given that, it was the first experience for those involved in the planning and execution of the OFR and farmers themselves were new in the area and from very different farming backgrounds.

The very wide range of yields complicated statistical analysis of the data, because of the absence of clearly defined relationships between environmental variables and management practices with final grain yields. The grain yields of the three bean cultivars were comparable but may not be repeatable due to the varying weather conditions experienced during the three seasons under review. Also, the final choice for recommendation will depend on the farmers' assessment.

With these restrictions the following conclusions can be drawn:

1. Kat MM produced better average grain yields than Rose Coco and Kat B1 overall and across stations and seasons (Figure 1), though the margins were small and there was much variation among individual farms.

2. The grain yields of Kat B1 were less than those of Rose Coco and Kat MM in the wetter second seasons of both years, when it was much affected by leaf blights.

3. In contrast, Rose Coco produced poorer relative yields in the drier first season.

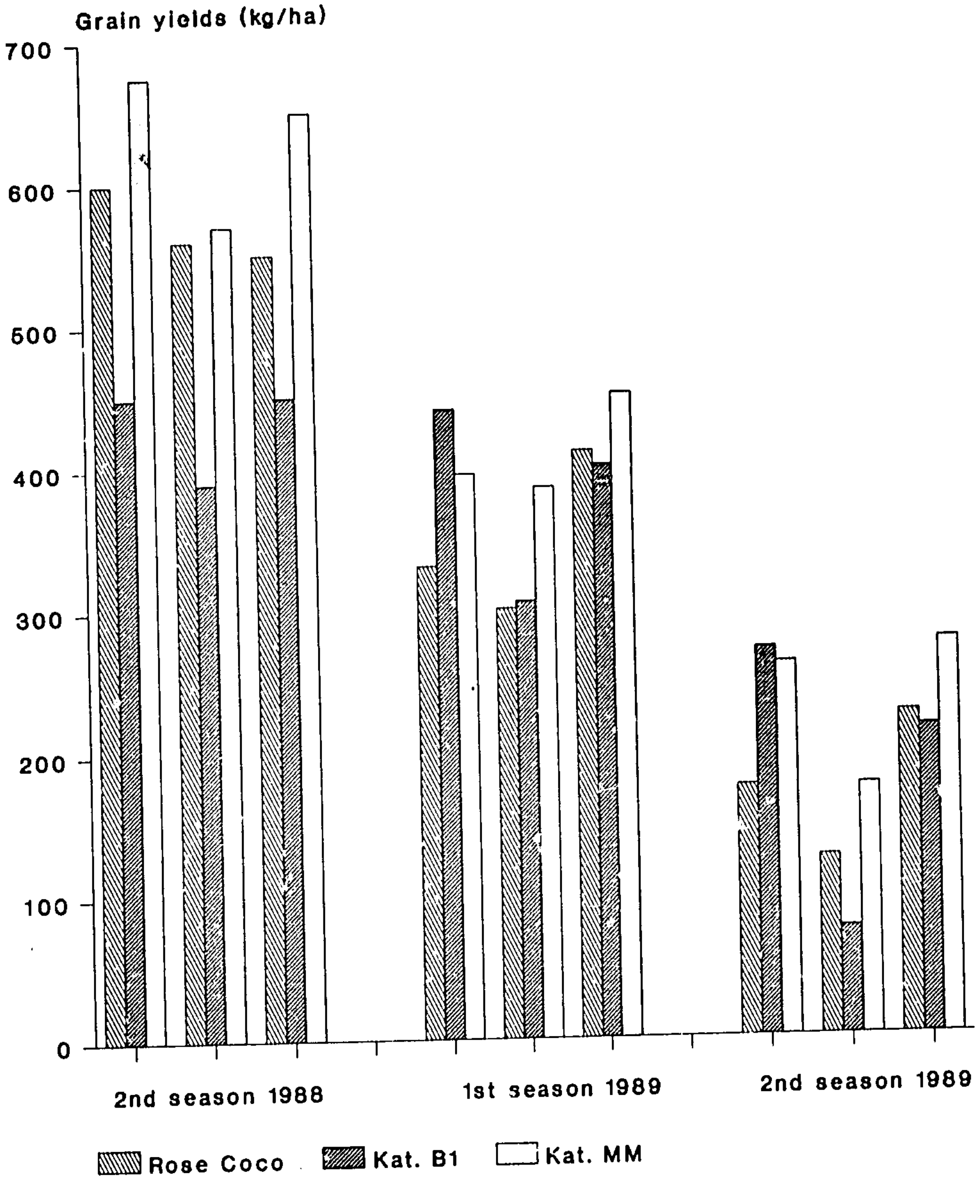
4. Kat MM and Kat B1 (90 days) matured earlier than Rose Coco (100 days).

5. Grain yields were affected greatly by individual farmer management, each farmer forming his own production class.

6. It is not possible to draw firm conclusions regarding the relative yields of the three entries from the results of only three contrasting seasons with very variable management practices.
7. Nevertheless, Kat MM has produced consistently better yields than Rose Coco and Kat B1 and is less affected by pests and diseases.

8. Bean grain yields in association with maize were poorer in the second season of 1989 than in the 2nd season of 1988 (sole bean), although rainfalls were similar. The maize had not been harvested when these results were summarized but generally, in maize:bean associations, maize yields are the same as those of a sole maize crop, while the bean yields are reduced by up to 50%. This gives an LER of at least 1.5, so associated cropping is much preferable.

Figure 1. Mean grain yields (kg/ha) in OFTs at Matanya from 1988 to 1989.



Socio-Economic Assessment

A socio-economic survey of farming systems has been continuously in progress. Initially involving the first 130 farmers, it then focused on the 20 who are active collaborators in the OFR. The survey is both informal and in a questionnaire form by field extension agents and a supervisory team. The survey aims at understanding farmers' socio-economic environments as it influences their farming systems. This will, hopefully identify bottlenecks in their existing production systems and thus help in the formulation of research priorities in the area.

Information on the major farm enterprises, wealth/income levels, social status, taste preference, farm management, marital life, family size, marketing of produce, credit facilities and household economy in general was collected for further scrutiny and analysis. Although this information has yet to be processed and analysed, our frequent interactions with farmers have revealed facts that are worthy of consideration in any extension recommendation.

1. Due to frequent crop failures, the majority of farmers do not rely on farm output. Hence one of more family members, especially men, are involved in wage employment in Nanyuki, Nyeri, Thika or Nairobi.

2. The majority of the farmers are poor and unable to purchase farm inputs like fertilizers, pesticides and seeds.

3. The uncertain weather makes investment in farm inputs more risky.

4. Credit facilities are non-existent, even though the high risk in defaulting in loan repayment due to unpredictable production is foreseen with available credit.

5. Bean plays a major role in meeting the food requirements of small scale farmers in Matanya. The beans are generally consumed at home in the form of *githeri* (maize and beans boiled together) or *irio* (beans mashed with maize, irish potatoes and green vegetables). *Irio* is a Kikuyu traditional dish rarely absent from homes where trials were conducted.

6. All farmers prefer Rose Coco, although they concede that Mwitemania produces some crop, even during bad seasons. However, they sell Mwitemania and buy Rose Coco for their home consumption. The local market price of all bean cultivars is the same although the gazetted price of Rosecoco is most.

7. Field management is mainly by women. For example, out of 28 farms: 14 farms were managed by women; 3 farms were managed by men; and 11 farms were managed by both women and men.

8. Mixed cropping of maize, bean and Irish potato is common practice. There is no relationship between the time of sowing of maize, bean and potato. Maize is sown always with the first rains, whereas bean and potato are cropped twice each year, usually from the onset of the rains.

Recommendations/Conclusions

1. There is need to consider and examine factors in the farming systems which influence the water balance under different management levels.

2. Time is not ripe to recommend any variety for extension services because yield stability and sustainability have not been established.

3. The OFR trials on beans should be repeated in the area but also extended to at least five other areas of similar agroecological conditions. The target for each recommendation domain should be at least ten farmers.

4. Development of manpower is mandatory with need for a full time agronomist supported by field extension agents well- trained to handle OFR.

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SUMMARY OF DISCUSSIONS

Teshome Girma

Bean lines with brown-speckled and medium-coloured seeds tend to be relatively better yielding than those with white seeds in poor yielding environments (for example, where rainfall is low), giving regressions less than unity.

Male-Kayiwa and Musaana

It was noted that line G 13671 varied in yield depending on locations. Black root drastically reduces yields of white-seeded types.

Farmers prefer large seeded types although they tend to produce poorer yields than cultivars with small seeds. Uganda scientists indicated that few bean cultivars with large seeds have been released to farmers. The presenter suggested that climbers may be evaluated, although lack of availability of stakes for support may pose a problem.

Location-specific evaluation was generally accepted over general stability in performance over locations.

Widely adapted materials are still being released in Uganda because such cultivars perform well in low input subsistence agricultural systems. K 20 is still being recommended for multiplication by seed companies in Uganda, although it is poor yielding, because farmers still grow it. It will be withdrawn later when a better large-seeded type is identified.

On the other hand, breeding in Kenya is for specific environments due to wide variation in climatic conditions.

Dr. Cardona expressed his feeling that stability analysis is not a very useful tool for selection.

Mohamed and Salih

In Sudan, the level of sodicity in soils where beans are grown is EC of about 20 mm/l. An EC of 4 mm/l is considered low.

Kimani *et al.*

The crop losses that justify initiating resistance breeding programmes are area-dependent, but 40% loss justifies resistance breeding in any situation. If resources and manpower are available, it can be initiated at less than 40%.

On a point of clarification, inoculations were carried out in the greenhouse from F_1 through F_3 and natural field infestations used in subsequent generations. Selection was practised as early as F_3, when inferior crosses are eliminated.

It was noted that breeders at times reject lines that farmers prefer, due to their susceptibility to diseases. It was agreed that released susceptible materials should not be discarded as yields may be increased by eliminating diseases.

Breeding in Kenya is for specific environments due to wide variation in climatic conditions and diseases. Significant genotype x location and genotype x year interactions indicate lack of stability which may be improved by breeding for resistance to particular environmental stresses and disease.

Muigai

The question of the population densities used in the intercropping studies was raised. In both pure and mixed crop systems, they were the respective standard recommended population densities.

Bean matured earlier and branched and podded more profusely in association with maize than in pure stand. Environment is thought to be the factor responsible for these differences. It was noted that during the study, planting dates were the same for both systems, approximating to those practised by farmers.

Another point is the bean materials developed under both mono and mixed cropping systems were examined. The maturity of bean in pure stand and association with maize did not differ significantly.

Lack of impact of high yielding varieties was said to be associated with poor adoption of new recommendations and cosmetic nature of experimental plots.

Kornegay

BCMV differentials are maintained in CIAT by Dr. Francisco Morales to ensure virus purity.

Seed transmission within and between I gene plants has been reported.

Materials resistant to *Macrophomina* sp are available at CIAT but more work is needed. In this and other work the large seeded varieties liked by farmers should be considered.

Mulagoli

One of the problems associated with OFR is lack of knowledge of research methodology.

Epidemiology, Control and Economic Importance of Bean Rust (Uromyces appendiculatus) in Mauritius

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Abstract

The incidence of bean rust (Uromyces appendiculatus) was monitored in monthly plantings from March to December 1986 using the highly susceptible variety, Long Tom. The disease was found to be more severe during the winter months with a peak of 25% in July. It was practically absent in summer. Seven fungicides were evaluated at two dosages for the control of the disease. Infection was reduced by all treatments. However, none of them significantly increased yield, except bitertanol (Baycor 300 EC) at 400 and 800 ml/ha. The results also indicated that foliar infection exceeding 5% has a deleterious effect on yield. In field trials to evaluate reaction to rust, 32 entries were rated resistant, 14 susceptible and 21 highly susceptible. Integrated control of the disease using chemical treatment, resistant cultivars and cultural practices is discussed.

Introduction

Bean rust, caused by *Uromyces appendiculatus* was first reported in Mauritius in 1937 (Orieux and Felix, 1968) and is considered one of the most important fungal diseases affecting common bean throughout the island. Environmental conditions that favour infection are high relative humidity and moderate temperatures (between 17 and 27 ^{o}C) (Schein, 1961a; Vargas, 1980), conditions which prevail over several months locally. The disease induces severe losses especially when infection takes place before flowering (Vargas, 1980). When no protective sprays are applied, losses ranging from 25 to 100% have been reported (Zaumeyer and Thomas, 1957; Stavely *et al.*, 1983). In Mauritius, the two most widely grown cultivars of red kidney bean, Long Tom and Local Red, are highly and very highly susceptible to the disease (Anon., 1987). Symptoms on these varieties can be very severe, such as upward rolling of leaves due to moisture stress, necrosis and defoliation. Pustules occur mainly on the lower surface of the leaf with a distinct yellow halo on the upper surface. Infection has not been observed on pods and stems. On account of the severe levels of infection observed in some locations at certain periods of the year, studies have been carried out recently in Mauritius on the epidemiology of the bean rust fungus and its control by fungicides, resistant cultivars and cultural practices.

Materials and Methods

Epidemiology

Plots of four rows of 10 m of the cultivar Long Tom were established monthly from March to December, 1986 at Bassin, situated in the west of the island. Routine insecticidal applications of Tamaron at 625 ml/ha were applied to control leaf miner, *Liriomyza trifolii*, and pod borers. Diseases were rated fortnightly at 4, 6, 8 and 10 weeks after planting corresponding to pre-flowering, flowering, pod formation and pod set stages of the crop cycle. Rust infection was estimated using the modified Cobb scale, as given by Galvez (1975).

Evaluation of Fungicides

A trial was conducted at Medine in western Mauritius in May, 1985. Plots of eight rows 7 m long of Long Tom were sown in a randomized block design of 15 treatments with four replicates. An untreated control was compared with seven fungicides, each at two doses: Baycor 300 EC (bitertanol) at 0.4 and 0.8 l/ha; Bravo 500 (daconil), Calixin M (tridemorph 11% and maneb 38%), Ronilan 50 (vinclozoline) and Rovral 500 (iprodione) at 1.0 and 2.0 l/ha; Bayleton 250 (triadimefon) at 0.5 and 1.0 kg/ha; and Dithane M45 (mancozeb) at 1.0 and 2.0 kg/ha. Four applications were carried out at ten day intervals with knapsack sprayers starting one month after planting. Control of insects and disease ratings were as described above. At harvest, pods in the middle rows of each plot were shelled, dried to constant weight at 98 ^{o}C and weighed.

Host Plant Resistance

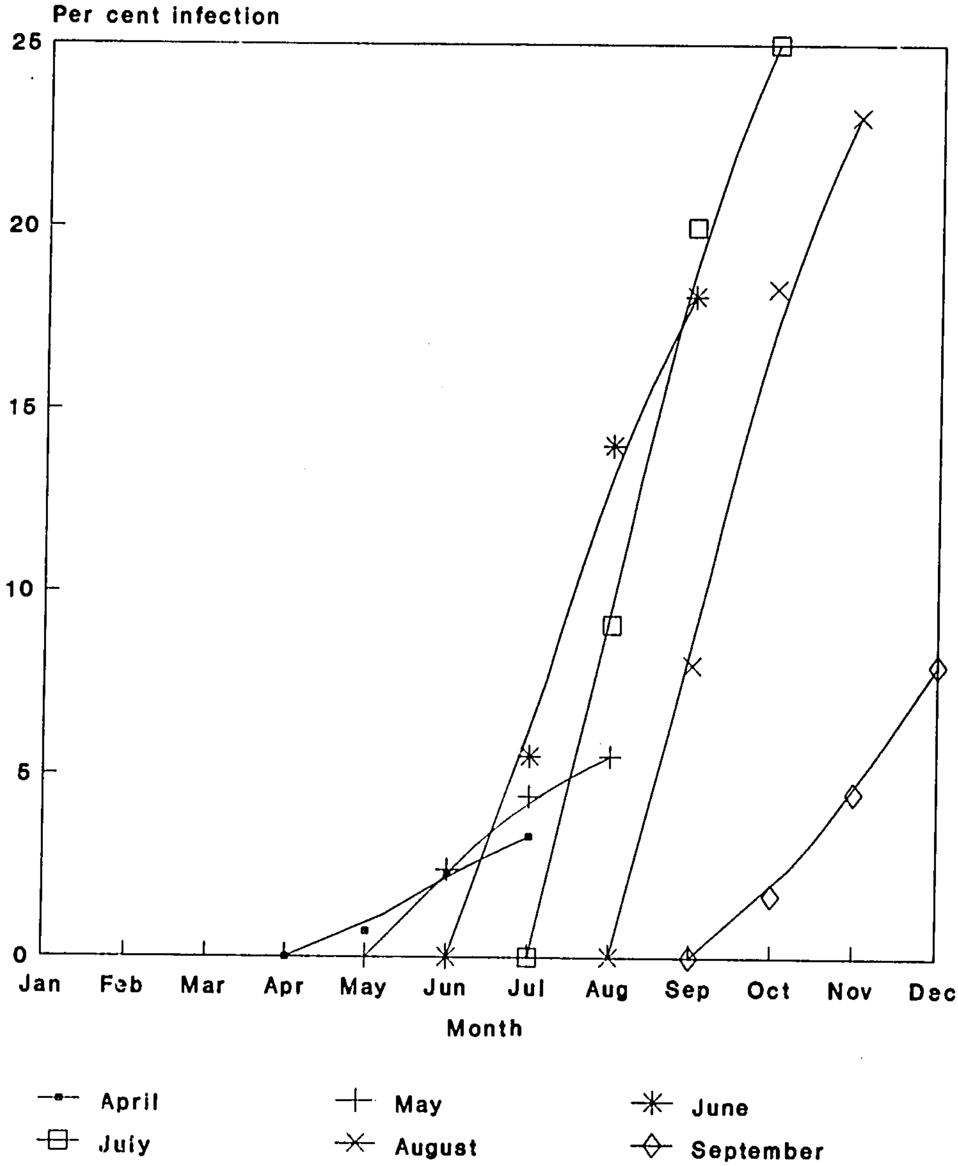
The rust reactions of 67 bean cultivars and lines were evaluated in a field trial in July 1987, at Reduit, in the centre of the island. The entries included 24 navy beans and 40 lines with coloured and 3 with white testas. They were grown in single rows 10 m long, adjacent to spreader rows of the highly susceptible cultivar, Local Red. Cultivars, Long Tom, Local Red and Teebus were included as controls. Final disease reactions were rated 8 to 10 weeks after planting as described above. Entries showing 0.5% rust were rated as resistant, while those with 6-10% infection were classified as susceptible. Infection in excess of 11% was considered highly susceptible.

Results

Epidemiology

Monitoring of rust in monthly plantings revealed that the disease was practically absent during the summer months from March to April and October to December when temperatures are high and evapotranspiration is rapid (Figure 1). However, as the weather became cooler, rust incidence rose sharply and became very important in June, July and August sowings. A peak of 25% infection was reached in the July sowing. There was little rust in the September sowing. This study showed that peak infection is limited to a well-defined period during the year.

Figure 1. Development of rust in bean sown monthly in 1986 at Bassin



No rust developed in March, October, November and December sowings

Evaluation of Fungicides

A high rust incidence of 36% was observed in plots that were not treated with fungicides (Table 1). Rust infection started one month after planting and rose rapidly to reach a peak after two months. Infection was reduced by all treatments. Baycor was the best fungicide for controlling rust at both 0.4 and 0.8 l/ha. With this chemical, the disease remained at only 1% and larger yields were obtained. There was little rust at the highest doses of Bayleton (6%) and Bravo (7%), but yields were significantly less than those obtained with Baycor. Also, rust was more severe at the lower dosages of these fungicides. Calixin M, Ronilan, Rovral and Dithane M45 were the least effective fungicides, although infection was reduced by them to some extent (Figure 2). The poor yields from the use of Calixin M and Dithane M45 were attributed to field variability and not to phytotoxicity.

Table 1. Efficacy of Foliar Sprays of Fungicides Applied at 10-day Intervals against Bean Rust.

Fungicide (and active ingredient)	Rate (kg or l/ha)	Percentage infection[a]	Yield[b] (t/ha)
Baycor 300 EC (bitertanol)	0.4	1	0.98a
	0.8	0	1.01a
Bravo 500 F (daconil)	1	12	0.54c
	2	6	0.67c
Calixin M WP (tridemorph 11%	1	17	0.38d
+ maneb 38%)	2	12	0.54c
Ronilan 50 F (vinclozoline)	1	25	0.41c
	2	14	0.48c
Rovral 500 F (iprodione)	1	20	0.42c
	2	14	0.54c
Bayleton 250 WP (triadimefon)	0.5	17	0.58c
	1	7	0.71bc
Dithane M45 80% WP (mancozeb)	1	18	0.39d
	2	10	0.58c
Untreated		36	0.47c

[a] 58 days after planting; [b] means followed by same letter do not differ significantly at P = 0.05

Host Plant Resistance

The inclusion of spreader rows in the assessment of cultivar reactions to rust was desirable so as to provide uniformity of inoculum. The level of rust in the trial was high and the spreader rows were rapidly defoliated. The 67 entries showed a range of reactions (Table 2). Thirty-two entries were rated resistant, 14 susceptible and 21 highly susceptible. With the exception of BAT 1453 and WAF 8, which were susceptible, all 22 navy bean entries were resistant to rust. In contrast, only 10 of the entries with coloured testas were resistant, the others being either susceptible or highly susceptible.

Figure 2. Effects of fungicides on development of rust in bean.

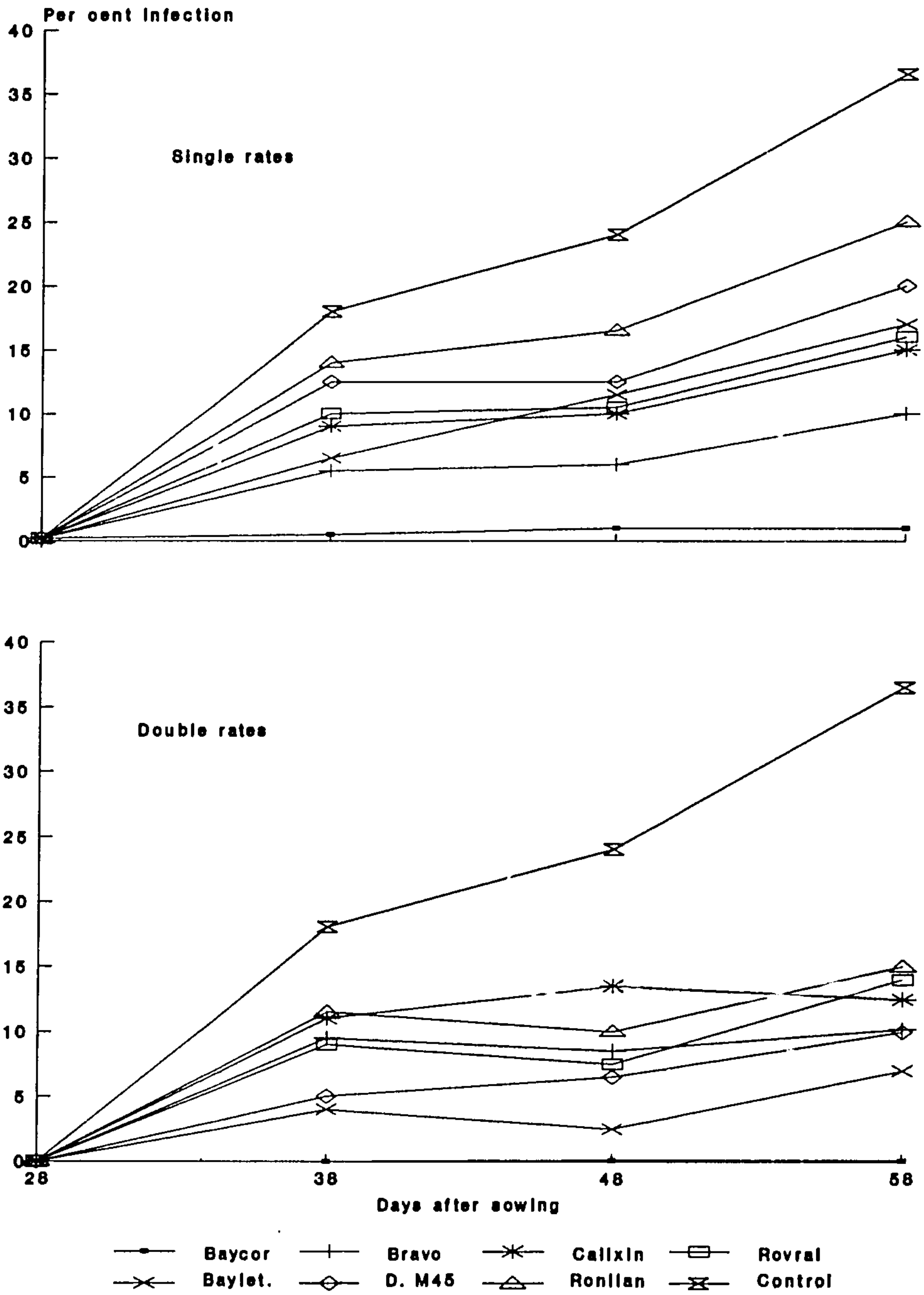


Table 2. Reactions of 67 Bean Cultivars and Lines to Rust.

Resistant (32)		Susceptible (14)	Highly susceptible (21)
Navy (22)	**Coloured (10)**	**Navy (2)**	**Coloured (19)**
Actolac	BAT 1230	BAT 1453	Bonus
Aurora	BAT 1296	WAF 8	Charlevoix
BAT 1712	BAT 1297		Cocorubico
BAT 1713	Linea 23	**Coloured (11)**	Local Red
BAT 1714	MCD 254		Long Tom
BAT 1715	MCD 257	Bonus Red	MCD 253
BAT 1717	Olathe	Isabella	MCD 256
Bunsi	PV 702	PV 791	Montcalm
C 20	PVA 1048	PVA 1063	PV 359
EMP 112	V 1299	PVA 1076	PVA 1067
Ex Rico 23		PVA 1082	PVA 1095
Fleetwood		PVA 1115	PVA 1097
Kambert		PVA 1117	PVA 1111
Kerman		PVA 1407	PVA 1145
Line 451		PVA 1453	PVA 1151
PAN 7		V 5003	PVA 1408
PAN 8			PVA 1435
PAN 22		**White (1)**	Rufus
RIZ 10			V 6003
Seafearer		Pharlap	
Teebus			**White (2)**
XAN 134			
			A 501
			Stella Bianca

Discussion

Epidemiological studies were carried out at only one location in order to study the evolution of rust during the period of commercial bean cultivation. It is known that continuous leaf wetness for 10 to 15 hours and moderate temperatures favour infection by *U. appendiculatus* (Hart and Saettler, 1981) while temperatures greater than 32°C may kill the fungus (Schein, 1961b). In Mauritius, conditions conducive to infection prevail in winter and this is demonstrated by the high rust incidence recorded during these months. In contrast, during summer, rust incidence was low as a result of temperatures approaching 30°C during the day and short periods of leaf wetness because of rapid evaporation. Under these conditions, the fungus is inhibited and disease levels remain low (Vargas, 1980). The susceptibility of the fungus to such environmental regimes suggests that the disease may be evaded by careful planning of planting schedules. However, such cultural practices may not be possible in Mauritius since the summer months coincide with the cyclonic period. The epidemiology of the fungus also indicates that due to heavy infection, fields of susceptible cultivars during winter should be treated with a fungicide as unsprayed ones will suffer reduction in yield.

Application of fungicides may be very effective in controlling rust. This is particularly important if infection occurs just before flowering as this is known to reduce yields severely (Vargas, 1980). Among the fungicides tested, Baycor kept the disease at a very low level. Being a contact fungicide, the rust pustules shrivelled in contrast to the other chemicals where only pustule numbers were reduced. Plants with 10-40 rust pustules per leaf can benefit from a spraying programme (Hart and Saettler, 1981). However, if there are more than 40 pustules per leaf (about 6% on the Cobb scale) throughout a wide area of the field, chemicals may not significantly increase yield. The results reported here are in agreement with these data since only Baycor, which kept infection below that threshold, increased yield significantly over untreated plots. Though fungicides such as Bravo and Bayleton were effective at higher dosages, the increase in yield was not as great as that with Baycor. However one drawback of Baycor is its long residual effect of 28 days in bean and there is a need for a fungicide with equal efficacy but with a much shorter residual effect to allow harvest sooner after spraying, as is needed for French bean.

The control of rust by host plant resistance may be effective in reducing losses, especially when cultural practices cannot be applied and fungicide treatments are not economically feasible. Several lines have been observed to be resistant to the disease, particularly navy bean types. However, great caution must be exercised since bean cultivars vary in their reaction to *U. appendiculatus* due to pathogenic variability of the fungus (Stavely, 1984a, 1984b). Commercial cultivars possess resistance to one or more races but none is known to be resistant to all races (Zaumeyer and Meiners, 1975). It is therefore important to determine the races that are prevalent in specific locations and evaluate the reactions of cultivars to them. In the long term, horizontal resistance is the best approach to rust control provided it can be found in better yielding backgrounds than currently grown commercial cultivars. Pending advent of such genotypes, disease escape practices with or without fungicide treatment are the most interesting ventures for bean producers to reduce impact of rust on yield.

Acknowledgements

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Identification of Components of the Bacterial Blight Complex of Bean in Mauritius, Their Relative Importance and Measures Adopted for Their Control

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Abstract

Two bacterial organisms causing fuscous blight (Xanthomonas campestris pv. phaseoli var. fuscans) and bacterial brown spot (Pseudomonas syringae pv. syringae) have been recently identified in addition to halo blight (P. syringae pv. phaseolicola) and common blight (X. campestris pv. phaseoli), which were known to occur previously. Identification was based on symptoms, biochemical and physiological tests, serological methods and phage typing. Common blight was most frequently encountered while brown spot was of rare occurrence. Climatic conditions were found to influence disease incidence with common blight being favoured in hot dry areas and halo blight in cool wet localities. Seed transmission of the four organisms was found to be of major importance in disease epidemics especially common and halo blights. Wounds by the leaf miner Liriomyza trifolii were found to increase disease spread especially of common blight. Foliar sprays of copper oxychloride and streptomycin seed treatment reduced the incidence of halo blight but not of common blight. Out of 56 entries evaluated in the field by the exposure method for their resistance to common blight, 17 were resistant, 19 moderately resistant, 8 slightly susceptible, 7 susceptible and 5 highly susceptible. Evaluation of 21 entries for resistance to fuscous blight by direct inoculation revealed that 1 was moderately resistant, 3 slightly susceptible, 10 susceptible and 7 highly susceptible. Navy bean was in general more resistant to bacterial blight than red kidney bean. Common blight was found to be the most important component of the bacterial blight complex and the need for resistant cultivars and disease free seed is emphasized.

Introduction

Within the framework of the diversification programme which has been implemented on sugar cane lands in Mauritius since the early 1970s, various crops including potato, maize, groundnut and tomato have been successfully grown on a large scale. Cultivation is mostly in sugar cane interrows and to a lesser extent between two crops. With a view to attaining self sufficiency in food production, other crops were looked into, that could fit within the restrictions of the programme, especially completion of the growth cycle within four months to enable interrow cultivation. Bean, *Phaseolus vulgaris*, was identified as one of them. Although this crop had been grown for a long time over the island as a vegetable, mainly the cultivar Long Tom, intensive cultivation was never practised on sugar cane lands. Mention should be made, however, of the production of French bean from November to March on a limited scale by some sugar estates since the mid 1970s for export to Europe. In

1984, research on bean was initiated at the Mauritius Sugar Industry Research Institute (MSIRI) on aspects such as evaluation of agronomic potential, cropping systems and biological constraints like diseases, pests and weed control.

Diseases of bean have long been recorded in Mauritius, the first being powdery mildew (Erisyphe polygoni), which was observed in 1915. Orieux and Felix (1968) listed some 14 diseases of which halo blight (Pseudomonas syringae pv. phaseolicola) and bacterial wilt (P. solanacearum) were of bacterial origin. Common blight (Xanthomonas campestris pv. phaseoli) was found in 1981 (Benimadhu *et al.*, 1984). A comprehensive research programme on disease identification, epidemiology, yield loss assessment, control and clean seed production was initiated in 1984 at the MSIRI. Part of the results obtained on the four organisms constituting the bacterial blight complex will be reported in this paper.

Materials and Methods

Field Surveys

Surveys were carried out in experimental plots, variety trials and seed and commercial fields of red kidney, navy and French bean to monitor incidence of bacterial diseases from 1984. Observations were made of the various syndromes present and their development during crop cycles at various locations and specimens were brought to the laboratory for further identification.

Isolation and Identification of Bacteria

Bacteria were isolated from leaves and pods on nutrient agar as described by Fahy and Persley (1983). Biochemical and physiological tests of suspected organisms were carried out according to the protocols elaborated by Schaad (1988). Determinations of thermal death point were made by treating bacterial isolates in hot water at temperatures between 40 and 65^{o}C followed by plating on nutrient agar and incubation at 27^{o}C.

Serological Tests

Agglutination tests were made with an antiserum to the halo blight organism supplied by Dr. J.D Taylor of the National Vegetable Research Station, U.K. Antigens were from pure bacterial cultures and sap extracts. Proper controls were included in the tests.

Phage Typing

Two phages supplied by Dr Taylor were used to differentiate the bacterial isolates. Ten microlitres of the phage suspensions were spotted on bacterial lawns on glycerol agar and plates were incubated at 27^{o}C over night.

Variation in P. s. pv. phaseolicola

Six isolates of halo blight were sent to Dr. Taylor for race identification by inoculation on a range of differential lines and laboratory tests comprising fluorescence, serology and phage specificity.

Effect of Cold Storage of Seeds on Bacterial Viability

Viability of the common blight organism in seed was monitored during cold storage at 2°C for a period of four months. Samples of 50 seeds each were tested at weekly intervals. Seeds were soaked in sterile water for two hours at room temperature and diffusates were plated on nutrient agar, followed by incubation at 27°C. Readings were made after 2 to 4 days.

Disease Carryover in Seed

Fifty seven samples of 50 seeds of cultivar Long Tom were taken at random from lots of seeds stored at 2-3°C at the Agricultural Marketing Board in 1986 and sown in the field. Seed infection was monitored after emergence and at weekly intervals until pod formation.

Control of Bacterial Organisms

In Vitro Tests

The effects of various concentrations of copper oxychloride between 5 and 50 ppm of copper and 50 and 500 ppm streptomycin on the bacteria were assessed *in vitro*. The antibiotics were incorporated in nutrient agar or placed in 5 mm diameter wells in agar plates inoculated with bacteria and incubated at 27°C. Zones of inhibition were measured after two to three days.

The effect of hot water treatments consisting of various temperature and time combinations ranging between 35 and 75°C and 5 and 30 minutes was assessed on the germination of seeds of Long Tom. Each treatment consisted of 100 seeds placed in layers of moist tissue paper and germination was assessed daily for seven days after treatment.

Glasshouse Tests

The effects of Agristrep on the germination of nine cultivars (Table 7) were assessed in a pot experiment in a glasshouse. The antibiotic was applied as a slurry at planting at 7.5 g/kg of seed, on 50 seeds per entry contained in one tray. Germination counts were made daily for three weeks and phytotoxicity monitored by visual observations throughout the growth cycle.

Field Tests

After preliminary trials which showed the inefficacy of 2.5 kg/ha copper oxychloride, which is currently used as a foliar spray against common blight, streptomycin was evaluated at 5, 10 and 15 kg/ha in comparison with the standard dosage and an untreated control. The trial (with cultivar Long Tom), was established at Pamplemousses Experimental Station in April 1970. The trial was in a randomized complete block design with four replicates and a plot size of 6 rows 7 m long. The development of bacterial diseases was assessed weekly during the crop cycle.

The efficacy of Agristrep (5% Streptomycin, Merck Inc. USA) at 7.5 g/kg of seed, applied as a slurry at planting, and foliar sprays of copper oxychloride at 2.5 kg/ha weekly from the second week after planting, for controlling seedborne infection, was assessed in a field trial. The treatments were applied alone and in combination. The trial was a randomized complete block with four replicates and a plot size of eight rows 7 m long. Surveys were made every two weeks throughout the crop cycle to monitor the incidence of bacterial diseases.

Identification of Resistance

The reactions of 24 bean cultivars and lines to common blight were assessed in a field trial under overhead irrigation in October 1984 by the exposure method. Each entry was sown in single rows 10 m long replicated four times. In 1986, visual observations were made on the same disease in 56 entries in 17 trials at various sites throughout the island.

The fuscous blight organism was inoculated on to 21 entries in a field trial at Pamplemousses in April 1989. Bacterial suspensions containing 1 x 10^8 cells per ml with 7 g/l carborundum 600 were applied with a mist blower, just before flowering. Disease progress was monitored weekly throughout the remaining crop cycle.

Results

Identification of Bacteria

Three syndromes were observed in the field. They comprised:

1. chlorotic lesions surrounded by a light yellow halo and greasy spots on pods;

2. large necrotic areas with an intense yellow halo and greasy spots on pods tending to brownish in certain entries; and,

3. small brown lesions of 3-4 mm on leaves with no symptoms on pods.

Isolations from leaves and pods with these symptoms on nutrient agar revealed the presence of four species of bacteria: halo blight, bacterial brown spot (*P. syringae* pv. *syringae*), common blight and fuscous blight (*X. campestris* pv. *phaseoli* var. *fuscans*). Common and fuscous blights were separated by the characteristic diffusible brown pigment produced in nutrient agar by *X. c.* pv. *phaseoli* var. *fuscans*. To differentiate *P. s.* pv. *phaseolicola* and *P. s.* pv. *syringae*, which produced identical colonies on nutrient agar, 17 biochemical and physiological tests were conducted (Table 1). Differences were mainly by the use of mannitol, inositol, sorbitol, erythritol, lactic acid and beta-galactosidase by *P. s.* pv. *syringae*, but not by *P. s.* pv. *phaseolicola.* Koch's postulates were satisfied in pathogenicity tests of the four organisms on Long Tom in a glasshouse.

Table 1. Biochemical Characteristics of Bacteria Causing Halo Blight and Bacterial Brown Spot of Bean.

Tests	Halo blight	Brown spot
Motility	+	+
Oxidase	-	-
Catalase	+	+
Levan production	+	+
Gelatin liquefaction	+	+
Starch hydrolysis	-	-
Nitrate reduction	-	-
Carbon utilisation		
Glucose	+	+
Galactose	+	+
Saccharose	+	+
Arabinose	+	+
Mannitol	-	+
Inositol	-	+
Sorbitol	-	+
Erythritol	-	+
Lactic acid	-	+
Beta-galactosidase	-	+

Suspensions (1 x 10^8 cells/ml) of pure cultures and crude sap extracts infected with *P. s.* pv. *phaseolicola* reacted positively with the antiserum supplied by Dr Taylor. The six isolates used in strain variation studies fluoresced in ultra violet light. The two phages, 12P and 48P, lysed cells of these six isolates but not those of the three other organisms as found by inhibition zones on agar lawns, 18 hours after incubation at 27°C. The isolates induced susceptible reactions on Canadian Wonder, Tendergreen and Red Mexican U13 and resistant reactions on Edmond. Together, these tests confirm that the six isolates were all race 2 of *P. s.* pv. *phaseolicola.*

Effect of Cold Storage on Bacterial Viability

Viability of *X. c.* pv. *phaseoli* var. *fuscans* in contaminated seed was reduced from 16 to 4% during cold storage for four months while that of *X. c.* pv. *phaseoli*, initially assessed at 24%, was not affected by cold treatment.

Disease Carryover in Seed

Out of 57 samples of seeds of Long Tom from the Agricultural Marketing Board, 15 were infected with bacteria including one case of coinfection with bean common mosaic virus (Table 2).

Table 2. Infection by Bacteria of Seed Consignments of Cultivar Long Tom stocked by the Agricultural Marketing Board.

Producer	No. of samples Tested	Infected	% infection	No. of samples
1	37	6	2	3
			4	1
			6	1
			4+2[a]	1
2	12	6	2	1
			3	3
			5	1
			10	1
3	8	3	2	1
			6	1
			14	1

[a] also infected with BCMV

Control of Bacteria

In Vitro Tests

Growth of cultures of *P. s.* pv. *phaseolicola*, *X. c.* pv. *phaseoli* var. *fuscans* and of *P. s.* pv. *syringae* were inhibited by 35 ppm of copper and that of *X. c.* pv. *phaseoli* by 45 ppm (Table 3).

Table 3. Effect of Copper Oxychloride on Bacterial Growth.

Organism	Copper oxychloride (ppm) 5	10	15	20	25	30	35	40	45	50
Common blight	++	++	++	++	++	++	++	++	-	-
Halo blight	++	++	++	+	+	+	-	-	-	-
Fuscous blight	++	++	++	++	++	+	-	-	-	-
Bacterial brown spot	++	++	++	+	+	+	-	-	-	-

++ = good growth; + = slight growth; - = no growth

Inhibition of *P. s.* pv. *phaseolicola* and *P. s.* pv. *syringae* occurred at 200 ppm of streptomycin and those of *X. c.* pv. *phaseoli* and *X. c.* pv. *phaseoli* var. *fuscans* at 250 ppm (Table 4).

Table 4. Diameters (mm) of Inhibition Zones due to Streptomycin[a] in Cultures of Bacteria isolated from Bean.

Organisms	Streptomycin (ppm)									
	50	100	150	200	250	300	350	400	450	500
Common blight	-	-	-	-	9	14	16	18	19	21
Halo blight	-	-	-	10	16	20	22	22	22	23
Fuscous blight	-	-	-	-	9	13	17	21	22	22
Bacterial brown spot	-	-	-	11	16	20	22	22	23	22

[a] Agristrep (Merck Inc., USA)

The thermal death points of *P. s.* pv. *phaseolicola*, *X. c.* pv. *phaseoli* var. *fuscans* and *X. c.* pv. *phaseoli* were 55, 60 and 63°C, respectively (Table 5).

Table 5. Thermal Death Points[a] of Bacteria attacking Bean.

Isolate	Organism	Source	Temperature (°C) and time													
			27	40	45	48	50	53	55	58	60[b]		63[b]		65[b]	
2983	Halo blight	Bassin	+++	+++	+++	+++	++	+	-	-	-	-	-	-	-	-
2984	Halo blight	Beau Plan	+++	+++	+++	+++	+++	+	-	-	-	-	-	-	-	-
2945	Common blight	Beau Plan	+++	+++	+++	+++	++	-	-	-	+	-	-	-	-	-
2946	Common blight	Medine	+++	+++	+++	+++	+++	+++	++	++	+	+	+	-	-	-
2953	Fuscous blight	Medine	+++	+++	+++	+++	++	++	+	-	+	-	-	-	-	-
3001	Fuscous blight	Cool store	+++	+++	+++	++	-	-	-	-	+	-	-	-	-	-

[a] plated on nutrient agar and incubated for two days at 27°C following hot water treatment; [b] for 5 and 10 minutes
+++ = profuse growth; ++ = moderate growth; + = slight growth;
- = no growth

Germination of seeds of Long Tom was not affected by temperatures up to 60°C for 5 minutes (Table 6). At 65°C for the same period germination was reduced by 33%, while at 70°C it was completely suppressed.

Glasshouse tests

Streptomycin reduced germination by 16.1% in BAT 1297, 23.5% in Long Tom and 40% in A 490 but that of the other cultivars and breeding lines was not affected (Table 7). In A 490, germination was delayed by 4 days. Phytotoxic symptoms were present in RIZ 10 but were transient as they disappeared two weeks after emergence. Growth and yield appeared unaffected by the antibiotic in all entries.

Table 6. Percentage Germination of Bean Seed of Cultivar Long Tom after Hot Water Treatment.

Time (min)	Treatment temperature (^oC) 35	40	45	50	52	54	56	58	60	65	70	75
0	99	100	97	97	98	98	99	99	100	99	99	100
5	99	99	96	99	99	99	99	87	87	66	0	0
10	99	99	86	97	96	70	65	55	27	8	0	0
15	99	99	85	81	80	83	41	20	0	0	0	0
20	100	100	91	74	66	55	7	0	0	0	0	0
25	100	100	86	66	50	35	0	0	0	0	0	0
30	100	100	77	45	16	13	0	0	0	0	0	0
35	98	96	78	37	15	14	0	0	0	0	0	0
40	100	93	80	27	13	11	0	0	0	0	0	0
45	99	91	79	21	12	8	0	0	0	0	0	0
50	98	94	80	12	5	4	0	0	0	0	0	0

Table 7. Effects of Streptomycin[a] on the Seed Germination of Nine Bean Cultivars and Breeding Lines.

Entries	% germination Treated	Untreated	Delay in emergence (days)	Chlorosis
A 490	48	80	4	-
Long Tom	65	85	0	-
BAT 1297	78	93	0	-
Pharlap	90	93	0	-
MCD 254	95	98	0	-
Teebus	95	98	0	-
RIZ 10	95	95	0	+
Ex Rico 23	98	98	0	-
Stella Bianca	100	93	0	-

[a] Agristrep applied as slurry at 7.5 g/kg of seed

Field Tests

The incidence of common blight, which was assessed at 25% in the untreated control, was not affected by foliar sprays even at 15 kg/ha of copper. The combination of seed treatment with streptomycin and foliar sprays of copper suppressed halo blight but also had little effect on common blight (Table 8).

Table 8. Effect of Seed Treatment with Streptomycin and Foliar Sprays of Copper Oxychloride on the Incidence[a] of Common and Halo Blight in Long Tom.

Treatment	Common blight %	Halo blight %
Untreated	100	100
Agristrep[b]	49	14
Cuprox[c]	91	27
Agristrep + Cuprox	39	0

[a] at flowering; [b] slurry at 7.5 g/kg of seed;
[c] foliar sprays at 2.5 kg/ha weekly starting one week after sowing

Identification of Resistance

In assessment of foliage and pod infection by common blight, out of 24 varieties, 3 were moderately resistant, 7 slightly susceptible, 10 susceptible and 4 highly susceptible (Table 9). From observations of 56 entries in various trials, provisional ratings were as follows: 17 resistant, 19 moderately resistant, 8 slightly susceptible, 7 susceptible and 5 highly susceptible (Table 10). The reactions of the 21 entries assessed for resistance to fuscous blight were: one moderately resistant, 3 slightly susceptible, 10 susceptible and 7 highly susceptible (Table 11). Inoculation with fuscous blight was justified in order to overcome common blight infection which could mask the former organism in the field. In general, navy beans were more resistant to both common and fuscous blights than entries with red kidney type seeds.

Relative incidence of bacteria in the field.

X. c. pv. *phaseoli* var. *fuscans* was isolated from fields of French bean cultivar Royal Nel in western Mauritius in March and May 1985. Infection was assessed at 40% of the plant population.

P. s. pv. *syringae* was found at three locations in northern, eastern and western Mauritius in cultivars Contender, BAT 1290 and Royal Nel in March-April 1985.

Halo and common blights were found in 25 and 18 fields of Long Tom surveyed in 1984 in northern Mauritius. In 1985, halo blight (at 2, 10 and 50%) was found in three fields of Long Tom, while common blight was present in seven of the eight fields surveyed, at levels of: 1% in V 3945; 3% in two fields of Long Tom; 10% in C 20; 25% in BAT 1297; and 25 and 50% in Long Tom. In 1986, halo blight levels reached 20% in some seed fields of Long Tom but was in general absent or at levels of only 3% in ware fields. In the same fields, common blight levels reached up to 60% (Table 12).

Table 9. Reaction of Bean Cultivars and Lines to Common Blight.

Entries	Percentage infection Foliar	Pod	Defoliation	Provisional rating
A 501	100	33	total	HS
MCD 253	100	10	total	HS
MCD 251	100	6	total	HS
MCD 252	100	4	total	HS
PV 1180	47	25	moderate	S
PV 791	40	15	moderate	S
A 490	38	trace	moderate	S
PV 702	37	22	moderate	S
BAT 1591	35	trace	moderate	S
Kerman[a]	35	trace	moderate	S
PV 781	30	12	moderate	SS
BAT 1592	28	trace	moderate	SS
Long Tom[a]	25	9	moderate	SS
BAT 1453	21	trace	moderate	SS
MCD 254	20	8	moderate	SS
EMP 112	18	trace	moderate	SS
MCD 256	45	28	slight	S
PV 359	45	15	slight	S
MCD 257	50	10	none	S
Teebus[a]	33	trace	none	S
Ex Rico 23	23	trace	none	SS
BAC 125	18	trace	none	MR
RIZ 10	16	trace	none	MR
78-0374	10	trace	none	MR

[a] standard cultivars; HS = highly susceptible; S = susceptible; SS = slightly susceptible; MS = moderately resistant

Comparison of the incidence of common blight in 12 cultivars under two contrasting environments showed that the disease was totally absent under cool moist conditions but present in 10 cultivars in a dry, hot environment (Table 13).

In a field in the subhumid zone of Long Tom for seed production, common blight infection was 10, 35 and 50% at 6, 8 and 9 weeks after planting in May-June 1986 in spite of weekly foliar sprays of copper oxychloride at 2.5 kg/ha. Common blight was consistently isolated from foliar lesions caused by the leaf miner, *Lyriomyza trifolii*. Halo blight proved to be important under cool moist conditions at Belle Rive Experimental Station in cultivars V 5003 (2% infection), Long Tom (3.5%), V 1299 (9%) and V 3945 (18%). Under the same conditions common blight was absent from these four lines. In a field of Long Tom in the superhumid zone at low altitude in 1985, halo blight was 5% on 24 September, 25% on 2 October and 80% on 15 October. This field was destined for seed production and had received weekly sprays of copper oxychloride at 2.5 kg/ha soon after sowing in late August. Seed production had to be abandoned.

Table 10. Reactions[a] of Bean Genotypes to Common Blight.

Resistant	Moderately resistant	Slightly susceptible	Highly susceptible
Aurora	Actolac	Charlevoix	Chevrette
Black Beauty	Belier	Early Bush	Long Tom
Kamberg	Bunsi	Stella Bianca	V 1299
Olathe	Cocorubico	Line 451	V 1844
Acc. No. 165426	Fleetwood	Acc. No. 109727	V 4493
GLP 24	Isabella	V 1837	
GLP 92	Linea 22	V 3945	
GLP 806	Local Red	V 6033	
PV 853188	Montcalm		
V 1154	Petit Rouge	**Susceptible**	
V 1825	Pharlap		
V 1840	Royal Red	Pompadour	
V 3210	Seafarer	Acc. No.165435	
V 4066	Acc. No. 313297	209	
V 4067	GLP 2	V 4141	
V 5593	V 1352	V 4604	
V 6209	V 1843	V 5003	
	V 2282	V 6203	
	V 6234		

[a] Provisional rating

Table 11. Reactions of 21 Bean Genotypes to *X. c.* pv. *phaseoli* var. *fuscans*.

Reactions	Red kidney	Navy
Moderately resistant		BAC 125
Slightly susceptible	PVA 1435	RIZ 10
		C 20
Susceptible	PV 791	Bunsi
	PV 359	Ex Rico 23
		XAN 134
		BAT 1592
		PAN 22
		A 490
		Aurora
		Teebus[a]
Highly susceptible	MCD 251	
	MCD 252	
	MCD 253	
	Montcalm	
	PVA 1076	
	V 5003	
	Long Tom[a]	

[a] control cultivars

Table 12. Occurrence of Common and Halo Blights (%) in 1986.

Category	Estate	Variety	Common blight	Halo blight
Seed	Beau Plan	Long Tom[a]	0	20
	Belle Vue (drip)	"	12	1
	Medine	"	2.5	0
	Medine	"	2	0
Ware	Medine (Beau Songe)	Long Tom[b]	60	3
	"	"	40[a]	2
	"	"	40	1
	"	"	40	trace
	Medine (Mon Desir)	"	2	0
	"	"	45	0
	Medine (Belle Vue)	"	17.5	0
	"	"	35	0
	Medine (Palmyre)	BAT 1297[b]	1	0

[a] imported from Holland; [b] local seed

Table 13. Comparative Incidence[a] of Common Blight at Belle Rive and Pamplemousses Experimental Stations in February 1985.

Cultivar	Belle Rive (superhumid)	Pamplemousses (dry/irrigated)
V 1299	0	0
RIZ 10	0	0
BAC 125	0	0.5
Kompasberg	0	0.5
Bunsi	0	0.5
Cocorubico	0	1.0
MCD 254	0	1.0
Teebus	0	1.5
Long Tom	0	3.0
Isabella	0	4.0
V 3945	0	4.0
V 5003	0	5.5

[a] Maximum per cent plants infected in crop cycle. Data confirmed in two trials in 1985 and three trials in 1986 at Belle Rive

Discussion

On the basis of cultural characteristics, biochemical, physiological and serological properties, phage typing, differential sensitivity to antibiotics and syndromes observed in the field and in pathogenicity tests, the presence of four bacterial pathogens is evident. Two of them (halo and common blights), are considered of major importance and the reports of Orieux and Felix (1968) and Benimadhu *et al.* (1984) concerning them have been confirmed. Bacterial brown spot and fuscous blight were encountered for the first time in Mauritius and are considered of minor importance. These two diseases have probably been introduced in recent years through infected seed as they are known to be seedborne (Yoshii, 1980; Schwartz, 1980). Although fuscous blight was the more frequently encountered of these two organisms, it has not assumed the importance that it has in other countries (Yoshii, 1980; Webster *et al.*, 1983).

Since common blight can easily mask fuscous blight and as they have similar syndromes, it would be interesting to have rapid methods of identifying them on a large number of crude sap samples by modern technology such as DNA hybridization probe as developed by Schaad *et al.* (1989) for halo blight and bacterial brown spot. The latter two can, however, be readily distinguished by visual symptoms.

Halo blight was found to be generally favoured in moist cool environments of the island, where bean is not grown on a commercial scale, preference being given to more profitable crops like potato. Furthermore, the beneficial effects obtained with combined treatment with streptomycin applied as seed treatment and foliar sprays of copper oxychloride, render control of the disease feasible, especially for eliminating seedborne infection and contamination. In addition, as race 2 only of the organism appears present in Mauritius, genotypes known to be resistant to this race should preferably be introduced as resistance is considered the main answer to halo blight control (Webster *et al.*, 1983).

Common blight is by far the most important component of the bacterial blight complex, as found elsewhere (Webster *et al.*, 1983; Yoshii, 1980). Its greater resistance to antibiotics both *in vitro* and in field tests, its higher thermal death point and its viability in seed stored at $2^{o}C$, render its control more difficult than the other three organisms. In addition, field surveys showed the common blight bacterium to thrive in warm relatively dry conditions, confirming data by Yoshii (1980). As such conditions prevail in localities where bean is grown on a large scale, sometimes under overhead irrigation, it is likely that common blight epidemics will become a regular feature, unless disease free seeds are used with surface or, better still, drip irrigation.

Crop rotation is also one of the measures advocated by Yoshii (1980) and Webster *et al.* (1983) for controlling common blight. Under normal circumstances in Mauritius, bean is grown interrow in sugar cane plantings and early ratoons during a crop cycle that may last for eight years or more. This cropping system would be suitable since it is unfavourable for the build up of common blight and other bacteria.

Emphasis should be placed on resistant cultivars, which are the main component of the final answer to bacterial blight control (Webster *et al.*, 1983). Methods of evaluating resistance have been designed especially for common blight (Redden *et al.*, 1985; Zapata *et al.*, 1985) and these methods should be applied systematically to introduced genotypes to identify those with the best resistance combinod with yields that exceed those of present commercial varieties.

In the control strategy, production of disease free seed is as important as cultivar resistance (Webster *et al.*, 1983). Thus, creation of nucleus seed stocks by hot water treatment at 65^{o}C for 5 minutes, followed by growth in agar *in vitro* before transfer to individual pots well separated from eachother in the glasshouse has been attempted with success (Anon., 1987; Autrey and Saumtally, unpublished). Nucleus stocks should be bulked in shade houses under insect proof conditions and drip irrigation, before final multiplication in the field with wider inter- and intra-row spacings than in commercial plantings, again with drip irrigation. Streptomycin should be applied to seed and copper as a foliar spray to minimize bacterial spread. Such a scheme is being implemented in Mauritius (Anon., 1989; Autrey and Saumtally, unpublished).

The introduction of airborne bacterial cells into wounds caused by *L. trifolii* requires that strict insecticidal spray schedules be followed in seed fields. Control of the leaf miner is an integral component of the clean seed scheme especially to ensure freedom from common blight. The exact role of the insect in the dissemination of common blight should be investigated. It could in fact transmit the bacterium with its ovipositor.

In spite of the limitations listed above and the fact that bacterial blights, especially common blight, can be symptomless (Cafati and Saettler, 1980), control of bacteria is possible but requires combined concern and attention as mentioned by various workers (Webster *et al.*, 1983; Yoshii, 1980). Integrated disease management is the approach which is being followed in Mauritius and there is confidence that it will be productive as otherwise bean production might be seriously jeopardized.

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Chemical Control Studies and Resistance to Bean Rust Uromyces appendiculatus (Pers.) Unger in Bean Germplasm

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Abstract

Studies of chemical control of bean rust Uromyces appendiculatus (Pers.) Unger on bean Phaseolus vulgaris L. cultivar Monel showed Anvil (hexaconazole) at 0.45 ml/l water to be excellent in controlling the disease, resulting in 4% yield gain. Baycor (bitertanol) applied separately at 0.6 ml/l was as effective when combined, 75% strength with Agridex (adjuvant), but did not increase the yield of green pods over that of the water sprayed control. The apparent phytotoxicity of Bayfidan to bean seemed to nullify its therapeutic advantage against bean rust. Evaluation of bean for rust resistance indicated cultivars Grofy and Metriot to be less susceptible than Monel. Of the dry bean cultivars, Red Haricot (TBH-11) expressed a hypersensitive reaction while Canadian Wonder (TBC-21) was as tolerant as Rose Coco (TBR-11) and better than Mwezi Moja (TBM-31), the dry bean most susceptible to the prevailing race(s) of rust.

Introduction

Bean rust, *Uromyces appendiculatus* (Pers.) Unger var. *appendiculatus*, is of economic importance particularly in the tropics, where yield losses ranging from 18-100 per cent have been reported (Vargas, 1980). The importance of rust on bean, *Phaseolus vulgaris* L., is a consequence of the airborne nature and foliar infection of the rust fungus. In eastern Africa, the disease has been a major factor limiting bean growing because it may reach epidemic levels any time during the vegetative stage of the crop resulting in crop failure (Macartney, 1966). Crop failure may result particularly if plants are infected during the pre-flowering and flowering stages of development (Vargas, 1980).

In Kenya, severe outbreaks of rust have been reported on bean grown for both dry seeds and green pods (van Rheenen *et al.*, 1981; Gerlagh, 1982; Omunyin *et al.*, 1984); these have been due primarily to lack of adequate control measures. Rust control strategies were the subjects of reports published by Howland and Macartney (1966), Macartney (1966) and Stoetzer and Omunyin (1983). It is accepted that the disease can be controlled effectively by use of fungicides and resistant cultivars (Vargas, 1980; Schwartz and Legard, 1982), the development and identification of which are continuous research exercises. The purpose of this study was to determine the efficacy of available fungicides in controlling bean rust and to evaluate bean materials for resistance to the rust fungus.

Materials and Methods

Chemical Control Tests

P. vulgaris cultivar Monel grown locally for green pod production and well known for its susceptibility to rust was selected for study. It was planted on 11 May 1989 at the Beans limited field, Thika (altitude 1545 masl), where rust has been a continuing problem. The treatments were arranged in a randomized block design with four replications. Each plot contained 400 plants spaced at 10 cm within and 50 cm between rows. The treatments, which included a water sprayed control, were: Baycor (bitertanol) 30% EC 0.6 ml/l of water; Baycor 0.45 ml/l plus Agridex (adjuvant) 1.5 ml/l; Agridex 1.5 ml/l; Anvil 0.45 ml/l; and Bayfidan 1.5 ml/l. All treatments were applied as sprays weekly for four weeks, commencing on 8 June, one day after the first disease rating.

Rust reactions were assessed on 7 and 23 June and 19 July. Ratings were on the primary and trifoliolate leaves of plants in the two middle rows of each plot. Rust severity was rated on a 1-9 point scale where: 1 = no visible symptoms or slight symptoms on leaves covering up to 1% of the tissue area; 3,5 and 7 = 5, 10 and 25% respectively, of leaf area covered; and 9 = 50% or more of the leaf area covered. Disease intensity was assessed by counting the number of rust pustules per cm^2 of leaf surface.

During ratings, plants were examined for evidence of any obvious effects of treatments. Also, a group of five visitors to the field were asked their opinions of plants of various treatments. At podding, green pods of fine grade (pods having a cross section 6.5-8.0 mm) were harvested at least once a week and weighed to determine yield. Analyses of variance were computed and means compared using Duncan's Multiple Range Test (Little and Hills, 1978).

Resistance Tests

The cultivars, Canadian Wonder (TBC-21), Rose Coco (TBR-11), Mwezi Moja (TBM-31), Red Haricot (TBH-11), Grofy, Metriot and Monel were used. Test plants were sown in a glasshouse in 16 x 30 cm pots on 13 June 1989 and seedlings thinned to two plants per pot. On 3 July, plants were transferred to a field plot of Monel, where rust spreader plants, established 45 days earlier, were spaced 10 cm within the row and 200 cm apart. At this time, the rust intensity on Monel was at least 24 pustules per leaf. The treatments were arranged in a randomized block design with four replications. The test plants, in pots, were placed 30 cm apart between the spreader rows and the plot received appropriate management with regard to plant water requirements and pest control. Rust reactions were rated on 19 July and the data analyzed in the usual manner.

Results

Fungicidal Tests

All fungicidal treatments significantly suppressed bean rust (P = 0.05) compared with the water sprayed control (Table 1). This was most evident on 19 July, following the fourth spray. At that time, plants treated with either Anvil, Baycor, Baycor plus Agridex or Bayfidan had less rust intensity than those of the control (Table 2). Only Bayfidan produced obvious effects on plant appearance or growth. The affected plants showed leaf curling and necrosis and reduced growth.

Table 1. The Effects of Fungicides on Severity of Rust on Bean Cultivar Monel at Thika in 1989.

Treatment	Disease severity rating		
	7 June	23 June	19 July
Baycor	1.45a	2.80a	1.25c
Baycor + Agridex	1.60a	3.64a	1.00c
Agridex	1.40a	3.20a	3.25b
Bayfidan	1.65a	4.55a	1.50c
Anvil	1.75a	3.35a	1.00c
Water (control)	1.65a	4.20a	4.75a

Means followed by the same letter are not significantly different (P = 0.05) according to Duncan's Multiple Range Test

Table 2. The Effects of Fungicides on Intensity of Rust on Bean Cultivar Monel at Thika in 1989.

Treatment	Disease severity rating		
	7 June	23 June	19 July
Baycor	2.30a	7.72b	1.09bc
Baycor + Agridex	2.45a	9.95b	0.19bc
Agridex	2.59a	7.43b	6.99ab
Bayfidan	3.75a	7.70b	2.03bc
Anvil	2.93a	6.00b	0c
Water blank	2.99a	24.45a	9.91a

Means followed by the same letter are not significantly different (P = 0.05) according to Duncan's Multiple Range Test

Plots treated with Anvil were rated best and produced the most green pods (Table 3), significantly more (P = 0.05) than those receiving Bayfidan or Baycor alone, 4% more than the control and 19% more than the next best fungicidal treatment, though these differences were not significant.

Table 3. Effects of Fungicides on Green Pod Weights of Bean Cultivar Monel at Thika in 1989.

Treatment	Green pod wt/plot (kg)	Rating
Baycor	4.53b	2
Baycor + Agridex	4.76ab	2
Agridex	5.04ab	3
Bayfidan	2.07c	4
Anvil	5.67a	1
Water control	5.46ab	3

Means followed by the same letter are not significantly different (P = 0.05) according to Duncan's Multiple Range Test

Resistance Tests

Only the cultivar Red Haricot (TBH-11) was resistant: it showed a hypersensitive reaction characterised by necrotic lesions without pustules (Table 4). This was most evident on 19 July, when no rust pustules were found on TBH-11, whereas they were present on all other entries. Among the other dry bean cultivars, which were all moderately susceptible, rust was less severe in TBC-21 than in TBM-31, which showed only 10% less rust than the susceptible, and TBR-11 was intermediate. Only the former was significantly less susceptible than Monel which was the French bean most susceptible to the prevailing race(s) of bean rust. Among the French bean cultivars, rust was significantly less severe in Grofy than in Monel.

Table 4. Reactions of Bean Cultivars to Rust at Thika in 1989.

Cultivars	Class of bean	Rust ratings		Reaction
		Intensity	Severity	
Rose Coco (TBR-11)	dry	4.00b	3.50bcd	MS
Mwezi Moja (TBM_31)	dry	4.63b	4.80ab	MS
Red Haricot (TBH-11)	dry	0a	1.00e	R
Canadian Wonder (TBC-21)	dry	5.63b	2.00de	MS
Grofy	French	4.50b	3.00cd	MS
Metriot	French	5.63b	4.00abc	MS
Monel (susceptible)	French	7.38b	5.30a	S

R = resistant - plants with necrotic lesions; MS = moderately susceptible - plants with small open pustules with spore production; S = susceptible - pustules coalesce with evident spore production and production of secondary rings
Means followed by the same letter are not significantly different (P = 0.05) according to Duncan's Multiple Range Test.

Discussion

The efficacy of fungicides in controlling bean rust is indicated by their ability both to reduce infection and increase yield (Vargas, 1980). Anvil was effective in controlling rust: at 0.45 ml/l, it significantly reduced infection compared with the control, resulting in a 4 per cent gain in green pod yield. Because it has no effect on plant growth, Anvil is preferred to other fungicides like Bayfidan, which caused browning of leaves and stunting of plants resulting in unacceptably low yields despite controlling rust.

Baycor, whether applied separately or in combination with Agridex, reduced rust infection but this was not reflected in yield of green pods which were no better than the control. Previous reports (Schwartz and Legard, 1982; Omunyin, unpublished) showed that Baycor applied as a wettable powder at least twice increased yield. It is not clear why Baycor as an emulsifiable concentrate failed to increase yield in similar or nearly similar conditions. Tests of formulations, application rates and phytotoxicity need expanding to clarify this issue.

Evaluation of bean cultivars for resistance to rust was an important aspect of this study. The cultivars were assessed on the basis of disease severity and divided into categories used previously; resistant, moderately susceptible and susceptible (Macartney, 1966; Schwartz, 1980). The variety TBH-11 was rated resistant because it showed necrotic lesions without pustules, an indication of hypersensitivity. To my knowledge, this is the first report from Kenya of a red haricot bean with this type of rust resistance. Five other cultivars were moderately susceptible; these included TBR-11, TBC-21 and TBM-31, previously known to be tolerant. In this study, Monel which is grown widely for green pod production, was quite susceptible, justifying efforts to develop measures for effective rust control.

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Preliminary Information on Seed-Borne Fungi of Bean (Phaseolus vulgaris L.) In Kenya

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Abstract

Twenty six samples of bean seeds obtained from Kisii, Kakamega, Embu and Kiambu Districts in Kenya were tested for seed-borne fungi using the Standard Blotter Method. Eighteen species of fungi were recorded: Fusarium moniliforme, F. semitectum, F. equisite, F. solani, F. oxysporum, Colletotrichum lindemuthianum, C. dematium, Macrophomina phaseoli, Rhizoctonia solani, Botryoidiplodia theobromae and Phoma, Cephalosporium, Verticillium, Cercospora, Rhizopus, Penicillium, Aspergillus and Cladosporium spp. Levels of seed infestation ranged from trace amounts to moderate (0.25-12%). However, 21 out of samples were infected with F. semitectum; 18 with F. oxysporum; 14 with F. moniliforme and 12 with Phoma spp. C. lindemuthianum, C. dematium, M. phaseoli, R. solani and Verticillium and Cercospora spp. were each recorded only once out of 26 samples.

Introduction

Common bean (*Phaseolus vulgaris*) plays an important role as an alternative source of relatively inexpensive dietary protein in Kenya (Schonherr and Mbugua, 1976). The annual total area under the crop in the country varies between 300 and 500 thousand ha. Average bean yields obtained (750 kg/ha in pure stand and 375 kg/ha in association with maize) are far below those obtained on experimental stations, the difference being attributed to a number of production constraints of which diseases and pests are the most important (Njuguna *et al.*, 1981).

Some important and moderately important fungal diseases - anthracnose (*Colletotrichum lindemuthianum*); angular leaf spot (*Phaeoisariopsis griseola*), ashy stem blight (*Macrophomina phaseoli*), fusarium root rot (*Fusarium solani f. sp. phaseoli*), rhizoctonia root rot (*Rhizoctonia solani*) and scab (*Elsinoe phaseoli*) (Njuguna *et al.*, 1981; Mukunya and Keya, 1975) are seedborne (Singh and Mathur, 1974; Mukunya and Keya 1979; Richardson, 1979; Buruchara, 1985). Seedborne pathogens play significant roles in disease transmission, depress seedling germination, may cause epiphytotics and reduce storage quality of the seed (Neergaard, 1979).

In Kenya, bean is mainly grown by small scale farmers as a mixed crop for subsistence purposes mostly using seed saved from previous harvests. There is limited use of certified seed although health tests are not carried out as routine. This means that the quality of much of the seed used in Kenya is not known. This paper reports preliminary information on the pathogens in bean seeds obtained from some parts of Kenya and used for sowing.

Materials and Methods

Seed Samples

Bean seed samples were collected from four districts: Kisii (6), Kakamega (4), Embu (2), and Kiambu (8). The seed obtained was what farmers claimed they used in sowing and was part of their previous harvest (short rains of 1987). They included Rose Coco (large and small), Canadian Wonder, Red Haricot and Mwezi Moja types. Six seed samples of the snap bean variety Monel were obtained from large scale commercial farms in Naivasha District.

Testing Methods

The seed samples collected were examined for inert matter, colour and presence of fungal fruiting bodies. Seed infection by seedborne fungi was determined using the Standard Blotter Method as described by Neergaard (1979). Ten seeds each were placed in sterile plastic petri dishes (9 cm in diameter) containing three layers of well-moistened blotters. The dishes were then incubated at $20 \pm 2^{o}C$ under alternating cycles of 12 hrs of near ultra-violet (NUV) light and 12 hrs of darkness. After 7 days of incubation, the seeds were examined under a stereo binocular microscope (6-50x) for fungal growth. Identification of the fungi was based on their growth habits and characteristics on the seed and spore characteristics observed under a compound microscope. Whenever necessary, the fungi were isolated and cultured on agar medium for further identification. For each sample, 400 seeds were tested as recommended by International Seed Testing Association (ISTA, 1985).

Results

A total of 18 fungal species were recorded on the seed samples tested (Table 1).

Fusarium species were the dominant fungal organisms recorded. Out of 26 samples: *Fusarium semitectum* was recorded on 21 samples; *F. oxysporum* on 18; *F. moniliforme* on 14; and *Phoma* spp. on 12. Although only *F. oxysporum* (fusarium yellows) and *F. solani* (fusarium root rot) are known to cause diseases of bean, seeds infected with other *Fusarium* spp. failed to germinate.

The level of seed infection was on average very small (0.25-12%) (Table 2). Bean pathogens, *C. lindemuthianum, M. phaseoli* and *R. solani* were each recorded in only one sample out of 26 and in trace amounts of seed infection (0.25%). The highest level of seed infection was 12% by *F. semitectum* on cultivar Monel.

Discussion

Seedborne pathogens are known to reduce the quality of stored seeds, seedling germination and vigour and depress crop yields. Mukunya and Keya (1979) noted the importance of seedborne inoculum of *C. lindemuthianum* in the development of anthracnose epidemics and yield losses in bean. Similarly, Tu (1989) observed that 88-100% of white bean seeds infected with white mould

Table 1. Numbers of Fungal Species Detected in Seed Samples of Different Cultivars.

Cultivar	Large Rose Coco	Small Rose Coco	Mwezi Moja	Canadian Wonder	Red Haricot	Monel	Total
Number of samples tested	4	10	1	4	1	6	26
Numbers of fungal species detected							
F. semitectum	4	10	0	3	1	3	21
F. moniliforme	3	6	0	2	0	3	14
F. equisite	0	5	0	1	0	4	10
F. oxysporum	2	10	0	2	0	4	18
F. solanum	1	3	0	0	0	3	7
Phoma spp.	1	5	0	1	0	5	12
Cephalosporium spp.	0	3	0	1	0	3	7
C. lindemuthianum	0	0	0	1	0	0	1
C. dematium	0	1	0	0	0	0	1
B. theobromae	1	0	0	0	0	0	1
M. phaseoli	1	0	0	0	0	0	1
Verticillium spp.	0	1	0	0	0	0	1
R. solani	0	0	0	0	0	1	1
Cercospora spp.	1	0	0	0	0	0	1
Aspergillus spp.	1	9	1	3	0	3	17
Penicillium spp.	1	7	1	0	0	0	9
Rhizopus spp.	0	0	0	1	0	2	3
Cladosporium spp.	0	3	0	1	0	2	6

Table 2. Percentages and Ranges (in parentheses) of Infection Observed of More Prevalent Fungi Recorded on Bean Seed Samples by Districts.

District collected	Kisii	Kakamega	Naivasha	Embu	Kiambu
Number of samples	6	4	6	2	8
F. semitectum	2(0.3-6.3)	3.1(1.85)	10.6(7.5-12.5)	0	1.6(0.3-3.0)
F. moniliforme	0.1(0-0.8)	0.5	0.75	0	1.4(0.5-2.3)
F. equisite	0.2(0-0.5)	0	0.2(0-2.5)	0	0.25
F. oxysporum	0.25	0.6(0-10)	2.6(1-4.8)	0	2.3(1-3.8)
Phoma spp.	0	0.9(0-1.8)	1.3(0.3-2)	0	0.25(0-0.8)

failed to germinate and that seedlings of infected seeds subsequently died from damping off. Seedborne pathogens are not only important in the quality of seed produced, but also for international transfer of seeds.

In the control of seedborne pathogens certain measures are used. These include use of resistant cultivars, enforcement of quarantine regulations, seed treatment and production of disease free seed. Use of seed health testing in the control of seedborne pathogens has been documented and has recently been reviewed by Mathur (1983).

The present study indicates that infection of bean seeds by seedborne pathogens is generally low to moderate in Kenya. This may arise from a number of factors. One is that, the seeds used in testing were from crops grown during the short rains. Under this situation, the incidence and severity of certain bean diseases may be less than in the long rains. In fact, it is a practice in certain parts of Kenya to cultivate bean during the short rains or towards the end of the long rains to avoid disease problems. It is also possible, that during harvesting and processing, farmers select and remove those seeds which show physical defects or discolouration, thus eliminating infected seeds. This partly explains the complete absence of *Phaeoisariopsis griseola* and only trace records of *Colletotrichum lindemuthianum*, despite both organisms causing widespread disease on bean in Kenya. Besides, detection of *P. griseola* on seeds is usually possible if infection or contamination occurs on or around the hilum, where the fungus visibly grows and sporulates.

Fusarium spp. were recorded in samples from all districts, implying widespread occurrence, but infection levels varied. Although *F. semitectum, F. moniliforme, F. equisite* and *Cephalosporium* spp. have been reported to be seed-borne on bean (Richardson, 1979), they are not known to cause disease. However, they are important seedborne pathogens of maize. Their occurrence at relatively greater frequencies than known bean pathogens is interesting a.d may result from contamination of bean seed, since intercropping of maize and bean is a common practice in the districts where the samples were obtained. It is, however, important to note that, bean seeds carrying these fungi rotted and failed to germinate. Their importance may be aggravated by the fact that they are also soil-borne and have wide host ranges (Richardson, 1979). This means that if introduced through seeds (either bean or maize), lasting problems may be created for other crops (Tarp *et al.*, 1987).

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Reactions of Bean Cultivars to Meloidogyne spp. in Kenya

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Abstract

Forty-seven bean cultivars were tested for their reactions to root-knot nematodes, Meloidogyne javanica and M. incognita in screenhouse and field at the National Horticultural Research Center, Thika. Of 47 cultivars tested, seventeen demonstrated root-knot gall indices of 2-3 to both nematode species. The cultivars were 37, 508, 355, 383, 411, 385, 462, 904, GLP-3, D-92, D-166, D-211, D-311, 552, GLP-X.1134, D-177 and GLP-X.1146. The root gall ratings indicated that these cultivars were moderately resistant to the two nematode species tested. All other cultivars were severely galled and loaded with the nematodes, so were regarded as susceptible to both nematode species.

Introduction

Dry bean (*Phaseolus vulgaris* L.) is the most important grain legume in Kenya (Muturi, 1976; Njuguna *et al.*, 1981). The average yields obtained by smallholders are 500 kg/ha (Thairu, 1979). These yields are low compared with other countries (Kirkby, 1987). The root-knot nematodes, *Meloidogyne javanica* and *M. incognita*, are limiting factors to bean production. These nematodes are widespread at lower altitudes particularly in irrigated areas (Kanyagia, 1979). The use of nematicides for root-knot nematode control is reported to be effective on various crops such as snap beans (Ogallo, 1988); brinjals (Kanyagia, 1984); carrots (Kanyagia, 1985) and others. The use of nematicides for control of root-knot nematodes on food bean is reported to be expensive and uneconomic, particularly for smallholders in Kenya (Ngundo and Taylor, 1974). The use of resistant cultivars is reported to be the most effective method and best approach for root-knot nematode control (Ngundo, 1977; Wyatt *et al.*, 1980; Moussa *et al.*, 1981). The following study was undertaken to evaluate the reactions of bean cultivars to *Meloidogyne* spp. in field and screenhouse in Kenya.

Materials and Methods

Forty-seven bean cultivars selected on the basis of their performance and commercial value were used in the tests. The first test was conducted in a field heavily infested with a mixed population of *M. javanica* and *M. incognita* race 2. The nematodes were established in the experimental field by growing a susceptible tomato cultivar (Toboga) for two seasons. The cultivars were tested in a randomized block design replicated four times. Each cultivar comprised twenty plants with a spacing of 75 cm between and 30 cm within rows.

After sixty days, plants were uprooted, washed in running water and scored for nematode damage using a gall index of 0-5 where: 0 = no galls or egg masses; 1 = 1-2; 2 = 3-10; 3 = 11-30; 4 = 31-100; and 5 = more than 100 galls or egg masses.

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

The second experiment was conducted in a screenhouse. Twenty plants were used for each cultivar. The seeds were sown in 17 x 22 cm polythene bags containing clay soil which was heavily infested with *M. javanica* (600 larvae/200 g soil). After sowing, the bags were kept on a bench and watered and sprayed with Dithane M45 whenever necessary. After sixty days, the plants were uprooted, washed free of soil with tap water and rated for nematode damage as described in the first experiment.

The third experiment was similar to the second except that soil infested with *M. incognita* was used. The roots were examined as described in the first experiment.

Results

The reactions of the bean cultivars to root-knot nematodes, *Meloidogyne javanica* and *M. incognita* race 2 are given in Tables 1 to 3. Out of 47 cultivars tested only seventeen demonstrated root-knot galling indices of 2-3 in all tests. These cultivars were 37, 508, 355, 383, 411, 385, 462, 904, GLP-3, D-92, D-166, D-211, D-311, 552, GLP-X.1134, D-177 and GLP-X.1146. They were regarded to be moderately resistant to both nematode species. Other cultivars exhibited root-knot galling indices of 4-5. The roots of these cultivars were heavily galled and loaded with egg masses, so were regarded as susceptible to both nematode species.

Table 1. Reactions of Bean Cultivars to *Meloidogyne* Species in Field Tests.

Cultivar	Mean root-knot index	Mean No. of egg-masses	Reaction	Cultivar	Mean root-knot index	Mean No. of egg-masses	Reaction
37	2	4	M	585	4	68	S
508	2	4	M	GLP-24	4	80	S
355	2	4	M	D-266	4	80	S
383	2	4	M	GLP-X.1127(b)	4	80	S
411	2	6	M	GLP-2	4	96	S
385	2	6	M	GLP-288	4	100	S
462	2	7	M	34	4	100	S
904	2	8	M	D-230	4	100	S
GLP-3	2	8	M	D-74	4	100	S
D-92	2	8	M	D-113	4	100	S
D-166	2	8	M	D-158	4	100	S
D-211	2	8	M	GLP-1290	4	100	S
D-311	3	15	M	575	5	>100	S
552	3	16	M	586	5	>100	S
GLP-X.1134	3	20	M	771	5	>100	S
D-177	3	28	M	B-19.1	5	>100	S
GLP-X.1146	3	30	M	B-86.2	5	>100	S
794	4	36	S	GLP-X.1150	5	>100	S
982	4	39	S	GLP-1159	5	>100	S
983	4	48	S	GLP-1160	5	>100	S
GLP-X.92	4	54	S	GLP-X.1301	5	>100	S
GLP-X.1135	4	55	S	GLP-806	5	>100	S
GLP-X.1124	4	60	S	GLP-X-1127(a)	5	>100	S
				GLP-1004	5	>100	S

M = moderately susceptible; S = susceptible

Table 2. Reactions of Bean Cultivars to *Meloidogyne javanica* in Greenhouse Tests.

Cultivar	Mean root-knot index	Mean No.of egg-masses	Reaction	Cultivar	Mean root-knot index	Mean No.of egg-masses	Reaction
37	2	4	M	585	4	69	S
508	2	4	M	GLP-24	4	80	S
355	2	4	M	D-266	4	82	S
383	2	4	M	GLP-X.1127(b)	4	88	S
411	2	7	M	GLP-2	4	97	S
385	2	7	M	GLP-288	4	98	S
462	2	7	M	34	4	100	S
904	2	P	M	D-230	4	100	S
GLP-3	2	8	M	D-74	4	100	S
D-92	2	8	M	D-113	4	100	S
D-166	2	8	M	D-158	4	100	S
D-211	2	8	M	GLP-1290	4	100	S
D-311	3	18	M	575	5	>100	S
552	3	19	M	586	5	>100	S
GLP-X.1134	3	20	M	771	5	>100	S
D-177	3	28	M	B-19.1	5	>100	S
GLP-X.1146	3	30	M	B-86.2	5	>100	S
794	4	36	S	GLP-X.1150	5	>100	S
982	4	39	S	GLP-X.1159	5	>100	S
983	4	50	S	GLP-X.1160	5	>100	S
GLP-X.92	4	52	S	GLP-X.1301	5	>100	S
GLP-X.1135	4	55	S	GLP-806	5	>100	S
GLP-X.1124	4	60	S	GLP- 1004	5	>100	S
				GLP-1127(a)	5	>100	S

M = moderately resistant; S = susceptible

Discussion

Bean cultivars exposed to soil heavily infested with *M. javanica* and *M. incognita* race 2 differed in their root reactions. Several were moderately resistant while others were susceptible to both nematode species. The roots of the moderately resistant bean cultivars had less galls and egg masses than the susceptible ones.

This confirms that some newly developed cultivars are moderately resistant to the two nematode species. However, most of the cultivars tested, including the recent released cultivars, GLP-1004, GLP-2, 585, GLP-24. GLP-X.92 and GLP-1127 were susceptible to nematodes. This was probably because resistance depends on the degree of host susceptibility and the species of nematode involved. The evaluation of bean cultivars for resistance to root-knot nematodes will continue this season, because the use of resistant cultivars is the best approach to controlling root-knot nematodes in beans in Kenya (Ngundo, 1977) and elsewhere (Wyatt *et al.*, 1980).

Table 3. Reactions of Bean Cultivars to *Meloidogyne incognita* in Screenhouse Tests.

Cultivar	Mean root-knot index	Mean No.of egg-masses	Reaction	Cultivar	Mean root-knot index	Mean No.of egg-masses	Reaction
37	2	3	M	585	4	62	S
508	2	3	M	GLP-24	4	75	S
355	2	14	M	D-266	4	80	S
383	3	15	M	GLP-X.1127(b)	4	80	S
411	3	15	M	GLP-2	4	96	S
385	3	20	M	GLP-288	5	>100	S
462	3	24	M	34	5	>100	S
904	3	24	M	D-230	5	>100	S
GLP-3	3	26	M	D-74	5	>100	S
D-92	3	28	M	D-113	5	>100	S
D-166	3	28	M	D-158	5	>100	S
D-211	3	29	M	GLP-1290	5	>100	S
D-311	3	29	M	575	5	>100	S
552	3	29	M	586	5	>100	S
GLP-X.1134	3	30	M	771	5	>100	S
D-177	3	30	M	B-19.1	5	>100	S
GLP-X.1146	3	30	M	B-86.2	5	>100	S
794	4	39	S	GLP-X.1150	5	>100	S
982	4	50	S	GLP-X.1159	5	>100	S
983	4	54	S	GLP-X.1160	5	>100	S
GLP-X.92	4	52	S	GLP.1301	5	>100	S
GLP-X.1135	4	56	S	GLP-806	5	>100	S
GLP-X.1124	4	60	S	GLP- 1004	5	>100	S
				GLP-1127(a)	5	>100	S

M = moderately susceptible; S = susceptible

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Research at CIAT on Bruchid Resistance

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Abstract

The bruchids, Zabrotes subfasciatus (Boheman) (Mexican bean weevil) and Acanthoscelides obtectus (Say) (bean weevil) are the two most important pests of stored beans in the world. Z. subsfasciatus is confined to warmer areas and is a warehouse pest. A. obtectus is a pest of cooler areas (higher altitudes or latitudes), infesting beans in the field and in storage. Excellent resistance to Mexican bean weevil has been found among wild Phaseolus vulgaris from Mexico. Resistance has been shown to be due to a protein (arcelin), which is easily detected (in the seed cotyledons) electrophoretically or serologically. Five variants have been identified, all simply inherited, and are being incorporated into cultivated backgrounds by backcrossing. Resistance to the bean weevil has also been identified in wild P. vulgaris from Mexico and is being transferred to cultivated types.

Introduction

The bruchids, *Zabrotes subfasciatus* (Boheman) and *Acanthoscelides obtectus* (Say) are the two most important pests of stored beans in the world, causing average losses estimated at 13%. The two species are similar but differ in their ovipositional habits. *Z. subfasciatus*, also known as the Mexican bean weevil, attaches its eggs to the seed testa while *A. obtectus*, the bean weevil, scatters its eggs among the seed. The insects also differ in ecological adaptation. *Z. subsfasciatus* is confined to warmer areas and is a warehouse pest which does not attack beans in undamaged pods. *A. obtectus* is a pest of cooler areas (higher altitudes or latitudes), infesting beans in the field and in storage.

Among the different bruchid control alternatives studied at CIAT, host plant resistance has received special attention. Following is a summary of present knowledge of resistance to bruchids, with special emphasis on the utilization of wild bean resistance sources to incorporate resistance into cultivated varieties.

Mexican Bean Weevil

The search for resistance to the Mexican bean weevil (MBW) was initiated in late 1977. No worthwhile resistance was found among more than 6,000 cultivated *Phaseolus vulgaris* types screened (van Schoonhoven and Cardona, 1982). Excellent sources of resistance to MBW were found among 380 wild *P. vulgaris* accessions collected in Mexico (van Schoonhoven *et al.*, 1983). Reconfirmation tests indicated that twelve accessions could be classified as highly resistant, 16 were intermediate and the rest were as susceptible as cultivated beans. Characteristically, wild resistant accessions are climbing, dehiscent beans with very small seeds (6 to 7 g per 100). Hard seed coat is common. Fortunately, wild beans can easily be crossed with cultivated forms.

Resistance to MBW in wild beans is due to antibiosis mechanisms (Schoonhoven *et al.*, 1983, Cardona *et al.*, 1989). There is a significant, deleterious effect on the biology of the insect: adult emergence is reduced, the life cycle of surviving insects is prolonged and progeny weight is reduced (Table 1). In addition, as shown in the oral presentation, antibiosis results in negative population growth rates, high mortality of late first instar or early second instar larvae, reduced female fecundity and male-biased sex ratios. By means of artificial seed techniques, Cardona *et al.*, (1989) demonstrated that the factors responsible for resistance are chemical in nature and are present in the seed cotyledons.

Table 1. Levels of Resistance to Bruchids in Selected Wild Beans Compared to a Cultivated Susceptible Variety.

Accession	Seed size (g/100 seeds)	Percent emergence	Days to adult emergence	Adult weight ($gx10^{-3}$)
Zabrotes subfasciatus				
G 12949	7	16.2	63.0	0.7
G 12952	6	17.4	65.2	0.7
G 12953	6	14.8	67.4	0.6
Calima (cultivated)	50	96.1	33.7	1.6
Acanthoscelides obtectus				
G 12891	8	31.6	52.1	1.8
G 12952	7	4.0	62.5	2.0
G 12954	6	7.2	55.1	1.0
Calima (cultivated)	50	78.4	36.6	2.6

Research on the factors responsible for resistance was initiated in 1985. Osborn *et al.*, (1986) identified a new protein (easily detectable by means of electrophoresis and/or serological tests) present only in wild MBW-resistant accessions. The protein was named arcelin (after Arcelia, the town in Mexico where most of the resistant accessions were collected). There are five arcelin variants, which according to Cardona *et al.*, (1990) have different genetic values (Table 2). Genetic studies indicated that the presence of arcelin is inherited as a single, dominant gene (Romero Andreas *et al.*, 1986) which can be easily transferred by backcrossing. When seeds of backcross-derived lines were tested at CIAT, all arcelin homozygous lines showed high levels of resistance to MBW, those heterozygous were intermediate and lines lacking arcelin were fully susceptible. Furthermore, the addition of purified arcelin to artificial seeds conferred very high levels of resistance to MBW (Osborn *et al.*, 1988).

Table 2. Effect of Five Arcelin Variants on the Biology of MBW[a]

Accession	Arcelin variant	% emergence	Days to adult emergence	Weight/adult ($gx10^{-3}$)	Index of susceptibility[b]
G 12882	1	9.3d	51.0c	0.9b	1.0
G 12866	2	20.5c	48.8c	0.9b	2.3
G 12922	3	79.5b	42.0d	0.9b	7.7
G 12952	4	8.4de	70.0a	0.5c	0.8
G 2771	5	4.0e	64.6b	0.8b	-0.3
Calima	-	94.0a	32.9e	1.4a	10.7

[a] Means of four tests, five replications per test. Means within a column followed by the same letter are not significantly different (P = 0.01; Duncan's multiple range test).
[b] Log progeny per female/days to adult emergence

These findings have greatly facilitated breeding for resistance to MBW. At present, a backcross breeding scheme is being utilized to improve beans for resistance to this pest (Table 3). All segregating populations are tested for the presence or absence of arcelin by means of a simple, reliable serological technique called the Ouchterlony plate. Seeds devoid of arcelin are discarded; those containing the protein are selected and handled as shown in Table 3. More than 100 MBW-resistant lines have been developed following this scheme. As an example, we present resistance levels of arcelin 1-derived lines coded RAZ (Table 4) which have been just released and incorporated in CIAT's 1990 VEF nursery.

Bean Weevil

Resistance to bean weevil (BW) was not found among more than 10,000 cultivated bean germplasm accessions screened between 1977 and 1981. In 1981, a handful of wild Mexican bean accessions showed high levels of resistance. Of these, 14 accessions have been reconfirmed to be highly resistant to BW. Some are also resistant to MBW.

As with MBW, antibiosis is the mechanism of resistance to BW (Table 1). Resistant accessions affect the biology of the insect causing high levels of larval mortality, prolongation of life cycles, staggering of generations, reduced female fecundity and male-biased sex ratios (van Schoonhoven *et al.*, 1983; Cardona *et al.*, 1989). Resistance was found to be due to chemical factors present in the cotyledon of seeds (Cardona *et al.*, 1989), the testa not being involved.

Table 3. Current Breeding Scheme to Incorporate Resistance to MBW into Cultivated Common Bean.

Resistant (arcelin-donor parent) x susceptible recurrent parent

F_1 :	backcrossed to susceptible parent
$BC1F_1$:	serological tests of 10-20 seeds per cross. Arc^+ are backcrossed to susceptible parent
$BC2F_1$:	serological tests of 10-20 seeds per cross. Arc^+ seeds are planted and individual plants are selected in the field
$BC2F_2$:	serological tests of 10-20 seeds per plant selected in $BC2F_1$. Homozygous Arc^+ are planted in progeny rows in the field and selected for agronomic characteristics
$BC2F_3$:	seeds are submitted to replicated feeding tests with the insect. Resistant progenies are planted in the field and selected for agronomic characteristics
$BC2F_4$:	best lines are coded RAZ

Table 4. Biology of, and Damage Levels by, MBW on Selected Dry Bean Lines Derived from Crosses with Parents Containing Arcelin 1.

Line/ cultivar	Type of cross[a]	% emergence	Days to adult emergence	Weight/adult ($gx10^{-3}$)	Index of susceptibility[b]	% seeds damaged 55 DAI[c]
Breeding lines						
RAZ 1	S	1.8b	53.0bc	1.2bc	-1.3	13.4bc
RAZ 2	T(BC2)	2.5c	53.9b	2.4a	-0.8	9.4c
RAZ 3	BC2	3.2b	51.8bc	1.3bc	-0.7	11.0bc
RAZ 4	S	2.9b	53.8b	1.3bc	-0.5	12.3bc
RAZ 5	S	3.4b	48.5c	1.1bc	-0.4	11.2bc
RAZ 6	BC2	4.3b	50.1bc	1.0bc	-0.2	13.6bc
RAZ 7	S	3.8b	49.5bc	1.2bc	0.07	21.0b
RAZ 8	T(BC2)	4.1b	51.2bc	1.0bc	0.06	16.3bc
RAZ 9	S	4.0b	50.2bc	1.2bc	0.3	14.8bc
RAZ 10	S	4.7b	50.8bc	0.9bc	0.3	17.5bc
Checks						
G 12952 (resistant)		5.4b	60.2a	0.7c	0.7	11.4bc
Pijao (susceptible)		99.4a	34.4d	1.4b	9.3	97.1a

[a] S = simple cross; BC2 = double backcross; T(BC2) = triple cross handled as BC2
[b] log progeny per female/days to adult emergence
[c] DAI = days after infestation
Means within a column followed by the same letter are not significantly different (P = 0.01; Duncan's multiple range test).

It is known from multiple tests that the presence of arcelin does not necessarily confer resistance to BW. Researchers at the University of Durham postulated that resistance to BW may be due, at least in part, to the presence of a heteropolysaccharide which has unusually high arabinose and fucose contents (Gatehouse *et al.*, 1987). This hypothesis has not been reconfirmed at CIAT or elsewhere and so far, a biochemical marker for resistance to this species has not been found. Consequently, resistance screening and selection in segregation populations must still be performed by means of time-consuming insect feeding tests.

Following an inheritance study which suggested that resistance to BW may be controlled by two recessive genes (CIAT, unpublished results; Kornegay, J., personal communication) a backcross breeding scheme has also been adopted to improve beans for resistance to this species. As shown in Table 5, segregating populations are tested with the insect in individual seed feeding tests. Though the lack of a chemical marker has made progress with BW a more lengthy process, high levels of resistance have been incorporated. At present, F_3 progenies are being tested in replicated trials.

Table 5. Breeding Scheme to Incorporate Resistance to *A. obtectus* into Cultivated Common Bean.

	Resistant x Susceptible
F_1 :	seed increased.
F_2 :	individual seed (200 seeds per cross) feeding tests with the insect. Resistant seeds are planted and backcrossed to susceptible parent.
$BC1F_1$:	seed increased.
$BC1F_2$:	individual seed (200 seeds per cross) feeding tests with the insect. Resistant seeds are planted and backcrossed to susceptible parent.
$BC2F_1$:	seed increased.
$BC2F_2$:	individual seed (200 seeds per cross) feeding tests with the insect. Resistant seeds are planted and selected for agronomic characteristics.
$BC2F_3$:	replicated feeding tests with the insect for each of individual plants selected in BC2F2. Resistant plants are planted and selected for agronomic characteristics.
$BC2F_4$:	replicated feeding tests with the insect for each of individual plants selected in $BC2F_3$. Resistant plants are planted and selected as above.
$BC2F_5$:	best lines are coded BRU.

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Distribution Patterns of the Bean Bruchids Zabrotes subfasciatus Boheman and Acanthoscelides obtectus (Say) (Bruchidae:Coleoptera) in Uganda

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Abstract

The bruchids, Zabrotes subfasciatus and Acanthoscelides obtectus, were found in all the zones of Uganda surveyed. Z. subfasciatus dominated in urban centres and Zone III. A. obtectus was the the cosmopolitan pest in rural areas with the greatest percentage composition in Agroecological Zones I, II and IV. The spread of Z. subfasciatus appears to stem from both trade in beans and their outflow from agricultural institutions. Weather may also influence its rate of establishment. It is the most serious pest in commercial urban storage and in rural storage in Zone III. A. obtectus appears to have been introduced much earlier than Z. subfasciatus and its spread has been accelerated by both its ability to fly and infest drying field beans and by the movement of beans. It is mostly established in areas with milder weather. Numbers of A. obtectus were generally small so that, in mixed populations, Z. subfasciatus predominated.

Introduction

Bean is widely grown in Uganda with annual productions of 197 thousand t in 1966, 223 thousand t in 1971-74 and 248,484 t in 1981-84. Since 1987, area has increased as a result of the prominent role bean has played as an export commodity for barter trade. Insect damage in store can be very heavy and greatly reduces the weight, quality and viability of beans. In 1962, weight losses due to insect pests were estimated to be as high as 5-10% after six months storage (Anon., 1962). It was estimated that 36-69% of stored pulses are bored by weevils. Surveys (Anon.,1989) showed that on-farm, losses of over 56% occur in beans during six months storage. Because of the heavy infestations and subsequent losses, farmers often opt to sell off the bulk of their produce soon after harvest. Where storage occurs, it is usually for short periods only or the beans are treated using mostly ashes and at times, chemicals (Anon., 1989).

The weevils, *Z. subfasciatus* and *A. obtectus* are the major pests of the common bean (*Phaseolus vulgaris*) and lima bean (*P. lunatus*). Both also attack seeds of other legumes including cowpea (*Vigna unguiculata)*, on which heavy infestations of *Z. subfasciatus* have been reported in Uganda and Burma (Meik and Dobie, 1986).

The rate of multiplication and the resultant damage is much greater with *Z. subfasciatus* than with *A. obtectus*. Field observations have shown that where infestations are predominantly *Z. subfasciatus*, either the losses are very high in untreated beans or various control methods are used (Anon., 1989).

Bean bruchids are thought to have originated from S. America (CIAT 1984), but are now widely distributed in bean producing countries world wide.

Early reports of the occurrence of *Z. subfasciatus* in Uganda have been reviewed by Davis (1972). *Z. subfasciatus* was first recorded in Uganda in 1956, when it was discovered in very small numbers on a lake barge at Port Bell near Kampala. However, extensive surveys of stored produce from 1956 to 1960 in all areas of Uganda except Kigezi District showed no presence of *Z. subfasciatus.* Nor was it found in surveys in Serere in 1960-61. In 1962 and subsequent years, it was recorded in considerable numbers on beans and cowpeas at Serere Research Station near Soroti and at Kawanda Research Station near Kampala. *Z. subfasciatus* was also recovered in 1967, from a sample of beans obtained from Bugisu District.

No early records of the occurrence of *A. obtectus* exist, except for occasional unpublished mentions. In 1988, it was found in association with *Z. subfasciatus* but in a much lower proportion in samples of beans from in and around Kampala (Dra, 1988).

Available evidence concerning patterns of distribution of *Z. subfasciatus* and *A. obtectus* indicate the importance of climatic and physical factors (van Schoonhoven *et al.*, 1986). *Z. subfasciatus* is found mostly in tropical areas of low altitude and relatively high temperatures, while *A. obtectus* is most commonly found in high altitude areas of cooler temperatures. There is no information on patterns of distribution of the two species nor on the factors involved in Uganda.

Materials and Methods

Sampling was conducted in representative districts of three of the four major agro-ecological zones of Uganda (Figure 1). Samples of bean and cowpea were collected from farms and households in rural areas and major collecting and distribution centres in urban areas (Table 1).

In rural areas, the sample population was divided into manageable proportions using multi-stage stratified random sampling. The sub-division was made on the basis of small administrative units. The units were chosen randomly with the final sample unit being the farm or household. The on-farm sample number was determined according to Harris and Lindbland (1978), with the range of expected losses of 35% and a desired precision of ±5%, which gave 35 to 60 on-farm sampling units.

Samples of 250 g were collected and kept in plastic containers. The samples were sieved to collect insects and then incubated for 45 days at room temperature for further sieving. The insects recovered were identified and counted.

Results and Discussion

The results are summarized in Tables 2 and 3 and Figures 2 and 3. Numbers of *A. obtectus* did not differ between samples from rural areas and urban centres while numbers of *Z. subfasciatus* were much greater in samples from commercial centres than in those from rural areas, for example in Kampala and Mpigi Districts in zone IV (Table 2) ($P<0.05$).

Figure 1. The Agroecological Zones of Uganda.

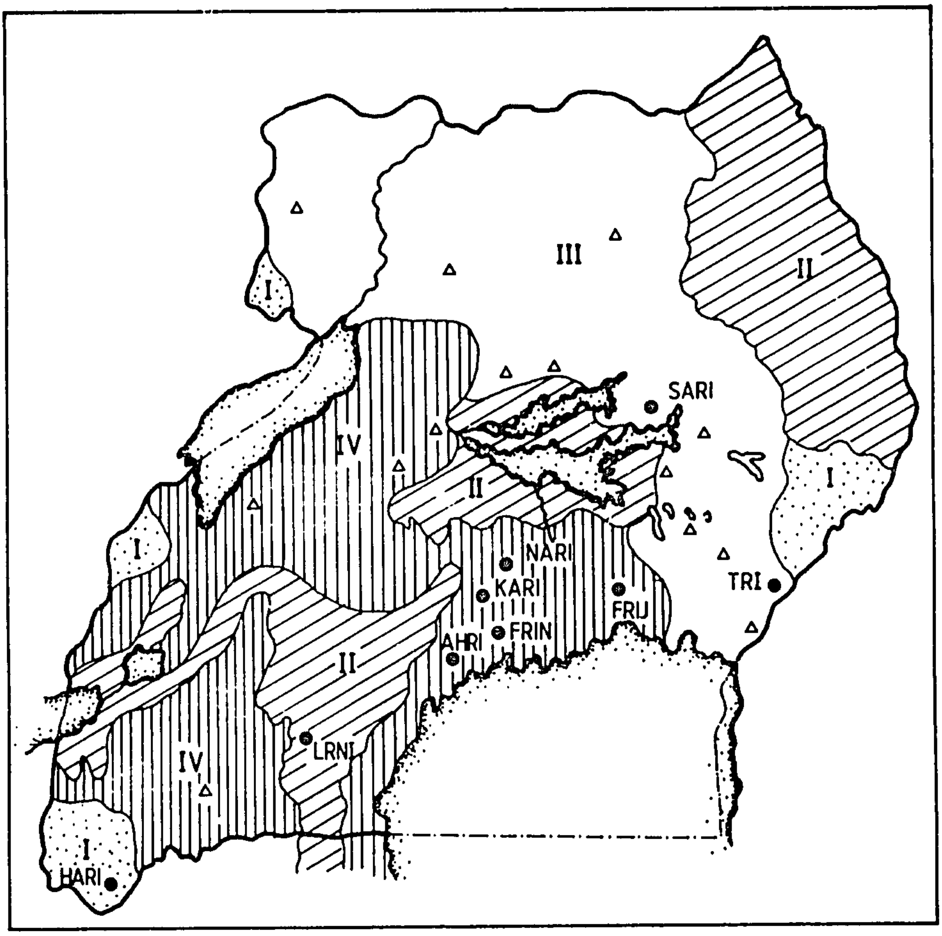

Table 1. Districts and Commercial Centres Sampled in Three Agro-Ecological Zones of Uganda.

Zone	Description	Districts	Urban areas
I	High altitude		
Sebei, Kigezi		Not sampled	
II	Pastoral, dry to semi-arid rangeland		
Moroto, E. Ankole, N. Buganda		Luwero	Luwero town
III	Short grassland, North and East		
Tororo, Soroti, Lira/Apac, Nebbi, Arua, Gulu/Kitgum		Lira	Lira town
		Apac	Apac
		Tororo	Tororo, Pallisa, Budaka, Busia
		Mbale	Mbale
IV	Tall grassland, South and West		
Masindi, Masaka, Hoima, Bundibugyo		Masindi	Masindi, Kigumba,
		Hoima	Hoima
		Mukono	Mukono
		Mpigi	Mpigi, Kawanda,
		Kampala	Kampala
		Masaka[a]	Masindi
		Mbarara[a]	Mbarara

[a] not sampled

Table 2. Numbers of *Z. subfasciatus* (Zs) and *A. obtectus* (Ao) Adults Recovered from 250 g Samples of Bean and Cowpea Collected from Rural and Urban Commercial Centres of Zone IV (Mpigi and Kampala).

Sample number	Rural		Urban	
	Zs	Ao	Zs	Ao
1	0	3	111	25
2	0	23	60	27
3	60	18	90	25
4	11	3	210	73
5	0	0	50	12
6	0	0	0	0
Mean	11.8	9.0	86.8	27.0
S.E.				

Figure 2. Percentage Composition of *Z. subfasciatus*.

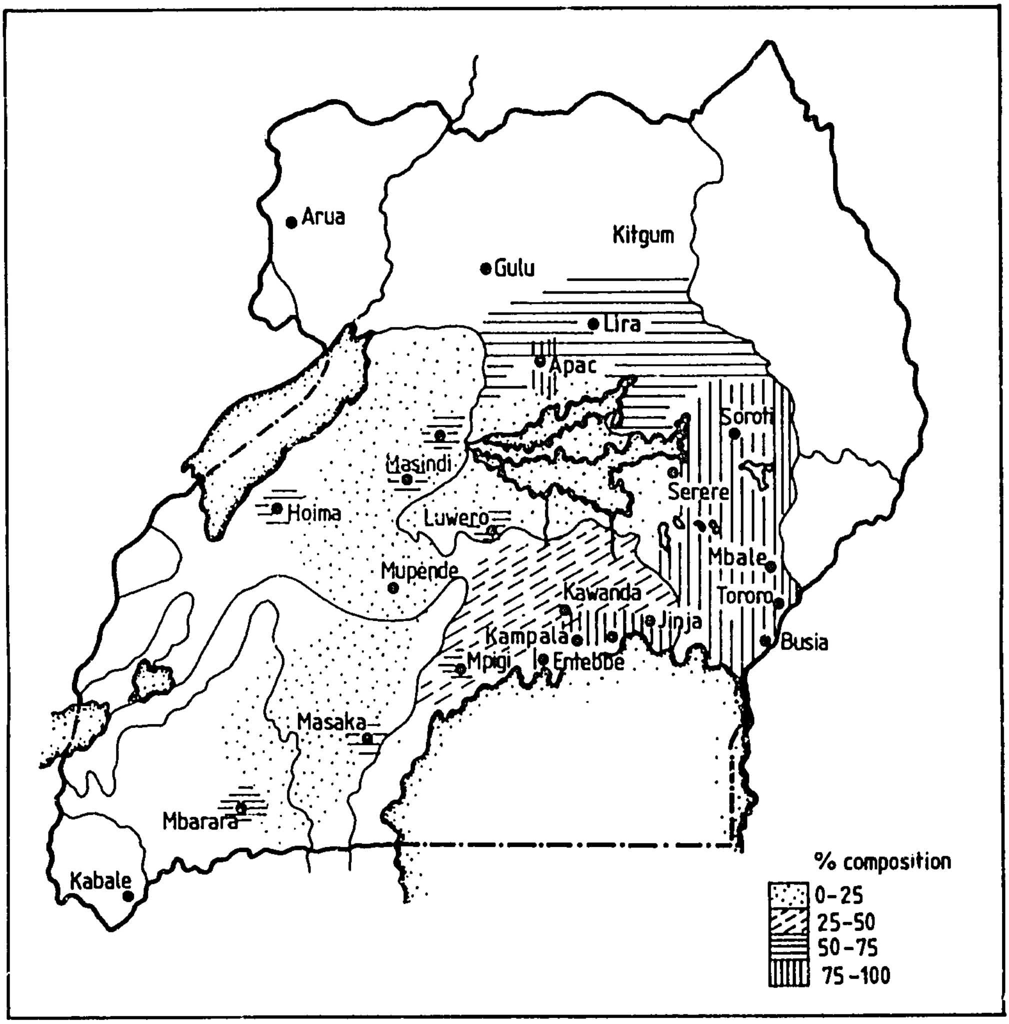

Figure 3. Distribution of *A. obtectus*.

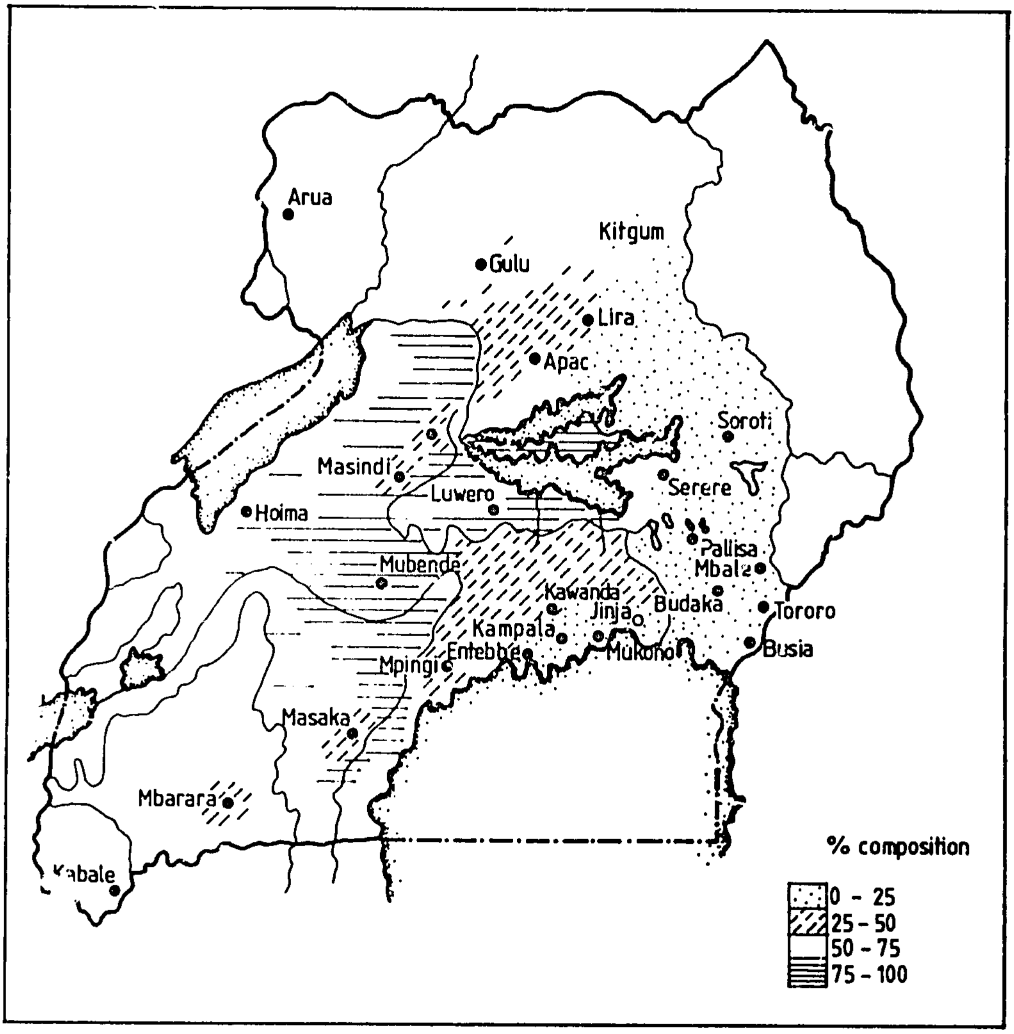

Table 3. *Z. subfasciatus* (Zs) and *A. obtectus* (Ao) as Percentages of Total Bruchids Recovered from Samples of Bean and Cowpea Collected from Rural and Urban Centres in Uganda.

			Zs		Ao	
Zone	District	Town	Rural	Urban	Rural	Urban
II	Luwero	Luwero	14.5	71	85.5	29
III	Lira	Lira	75.5	85	24	15
	Apac	Apac	72.5	79.1	27.5	20.9
	Tororo	Tororo	87.5	95.1	12.5	4.9
		Pallisa		93.4		6.6
		Budaka		88		12
		Busia		87		13
	Mbale	Mbale	58.7[a]	81.1[a]	41.3[a]	19.9
IV	Masindi	Masindi	4	59.1	96	40.9
		Kigumba	64.9	64.9		35.1
	Hoima	Hoima	0	39	100	61
	Mukono	Mukono	49.5	89.9	50.9	10.1
	Mpigi	Mpigi	50.1	71.1	49.9	28.9
		Kawanda		81.3		18.7
	Kampala	Kampala	NC	87.1	NC	12.9
	Masaka	Masaka	69	69.1		30.3
	Mbarara	Mbarara	NC	59.9	NC	40.0

NC = not collected; [a] lowland areas only

The two weevils, (*Z. subfasciatus*) and (*A. obtectus*) are obviously well established pests of bean in Uganda, being found in all the three agro-ecological zones sampled. The percentage composition of the two bruchids in infested beans varied among zones, between rural and urban centres and among rural centres of the same zone.

In samples from most urban centres, *Z. subfasciatus* predominated, with the highest percentage composition found in the corridor running Entebbe-Jinja-Tororo-Soroti. Pockets of high populations were also found in the towns of Lira and Apac and *Z. subfasciatus* also predominated in Zone III.

A. obtectus predominated in samples from rural areas, with the largest percentage compositions in Zone II and in Zone IV, except for the southern areas. It is also believed to dominate *Z. subfasciatus* in Zone I.

The pattern of distribution of *A. obtectus*, covering almost the entire country, suggests that it was either introduced much earlier than *Z. subfasciatus* or that it has a better ability to spread. Where bean infestations were predominantly by *A. obtectus*, sparse populations were accompanied by little damage.

The pattern of the population distribution and spread of *Z. subfasciatus* accords with its recent introduction into Uganda (Davis, 1972). The occurrence of the pest in areas from which it was earlier absent, however, indicates that it is still spreading. Initial records of *Z. subfasciatus* in Uganda - at Serere and Kawanda Research Stations, on a barge on Lake Victoria and at a cooperative warehouse in Mbale (Davis, 1971) - suggest its spread may be via outward movements of beans from major research stations and by commercial movements.

Climatic factors may then have influenced the rate and degree of spread of *Z. subfasciatus* and its establishment in the different agro-ecological zones of Uganda (van Schoonhoven *et al.*, 1986). Current findings tend to confirm this. For example, where high incidences of *Z. subfasciatus* are found, as in Zone III, temperatures are high, with maxima of 30°C common.

In rural areas, low populations of *A. obtectus* occurred and were more evenly distributed. Although the reasons are not clear, it is possible it has reached a more controlled and balanced population as a result of natural biological agencies, or simply that its reproductive capacity is lower in some areas. More investigation is required. Normal grain movements coupled with the ability of *A. obtectus* to perform flights and infest even field dried beans are thought to have contributed to the spread and even distribution of *A. obtectus*.

The establishment and predominance of *A. obtectus* in the cool zones is thought to be due to its tolerance of temperatures too cool for *Z. subfasciatus*.

Where mixed populations occurred, *A. obtectus* were fewer than *Z. subfasciatus*, so *Z. subfasciatus* may have a competitive advantage. Other biological and physical factors influencing population numbers may also be affecting *A. obtectus* more than *Z. subfasciatus*. More work is needed to determine the reasons for this trend.

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Effects of Ash and Cultivar on Population Densities of the Bean Weevil, Acanthoscelides obtectus

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Abstract

Concentrations of ash which reduce bruchid infestation and damage on bean without creating inconvenience in post-storage handling are not well known in Uganda. It is also not clear whether there are bean cultivars which are resistant or less susceptible to bean bruchids. Studies were initiated to determine the effects of ash concentrations and bean cultivars on population density of bean bruchids and their damage. Three concentrations of ash (0, 1 and 5% by weight) were applied to seeds of three bean cultivars (Haricot, Nambale and Kanyebwa). After 12 weeks there were 72, 30 and 14 bruchids/20 g of beans at 0, 1 and 5% concentrations of ash, respectively. Ash also affected time to peak population density: the greater the ash concentration, the shorter the time to peak population. The damage resulted in 23.8, 11.7 and 2.1% weight losses at 0, 1 and 5% ash concentrations, respectively. Kanyebwa appeared most susceptible (40 adults/20 g of beans), followed by Nambale (19 adults/20 g) and Haricot. There was a significant interaction between ash concentrations and cultivars: at 5% ash, losses in weight were 2.2, 2.9 and 2.7% for Haricot, Nambale a Kanyebwa, respectively, This suggests that the use of resistant cultivars could substitute for ash.

Introduction

Attack by a number of field and storage insect pests is one of the factors limiting yields of bean in Uganda. It is believed that the bean seed beetles, *Acanthoscelides obtectus* (Say) and *Zabrotes subfasciatus* (Boh), alone cause significant losses in weight of beans in store (Rubaihayo *et al.*, 1981; Owera, 1987). For example, it is estimated that 38% of beans are bored after storage for six months (Davies, 1962; Hall, 1970). Davies (1962) and Byaruhanga (1973) estimated that this damage resulted in 10-22% loss in weight of beans stored for over three months.

Control of storage insect pests of beans in Uganda emphasized the use of insecticides. A number of chemicals including gamma BHC, malathion and lindane have been tested and recommendations made for the control of storage pests of bean (Anon., 1953, 1961, 1962; Davies, 1962). Few farmers, however, follow recommendations (Sengooba, 1987). This may be due to the high cost of the insecticides and fear of poisoning themselves and the environment. Furthermore the use of chemicals has not, in a majority of cases, solved the problem of storage pests on bean (van Rheenen *et al.*, 1983). In Uganda, this would appear to be due to bruchids developing resistance against chemicals. For example, Evans (1985) found that *Callosobruchus maculatus* and *Z. subfasciatus* from Uganda were resistant to malathion and lindane. There is therefore need to look either for new chemicals or for alternative means of controlling storage pests of bean. Promotion of traditional means of protecting beans offers such an alternative.

A number of materials, including ash, banana juice, termite-mound soils, pepper and vegetable oil are used by peasant farmers in Africa to protect beans against storage insect pests (CIAT, 1986). Research elsewhere has indicated that some of these are very efficient in controlling storage pests (van Schoonhoven, 1978; CIAT, 1986). Mixing beans with ash is one of the methods that is very effective and could perhaps be recommended for the control of bruchids on bean in Uganda. This control method could further be enhanced by use of resistant cultivars. However, very little has been done on ash as a protectant: the rates and times of application are not known. Furthermore, bean genotypes which are resistant to bean bruchids have yet to be identified.

The objectives of the preliminary study reported here were:

i. to determine the effect of different levels of ash on bruchid populations and their damage to beans; and

ii. to study the effect of the commonly grown bean cultivars on population densities of bruchids.

Materials and Methods

The study was conducted in a laboratory at Makerere University in Uganda. During the study period, room temperatures varied between 23.5 and 26°C and relative humidities between 50 and 80%.

Treatments consisted of three levels of seed dressing with ash (0, 1 and 5% by weight) and three bean cultivars (Kanyebwa, Nambale and Haricot). The ash was from charcoal whose tree species was not known. The cultivars were those most commonly grown in Uganda. The seeds used had just been threshed and were free from any chemical treatment. The treatments were replicated three times.

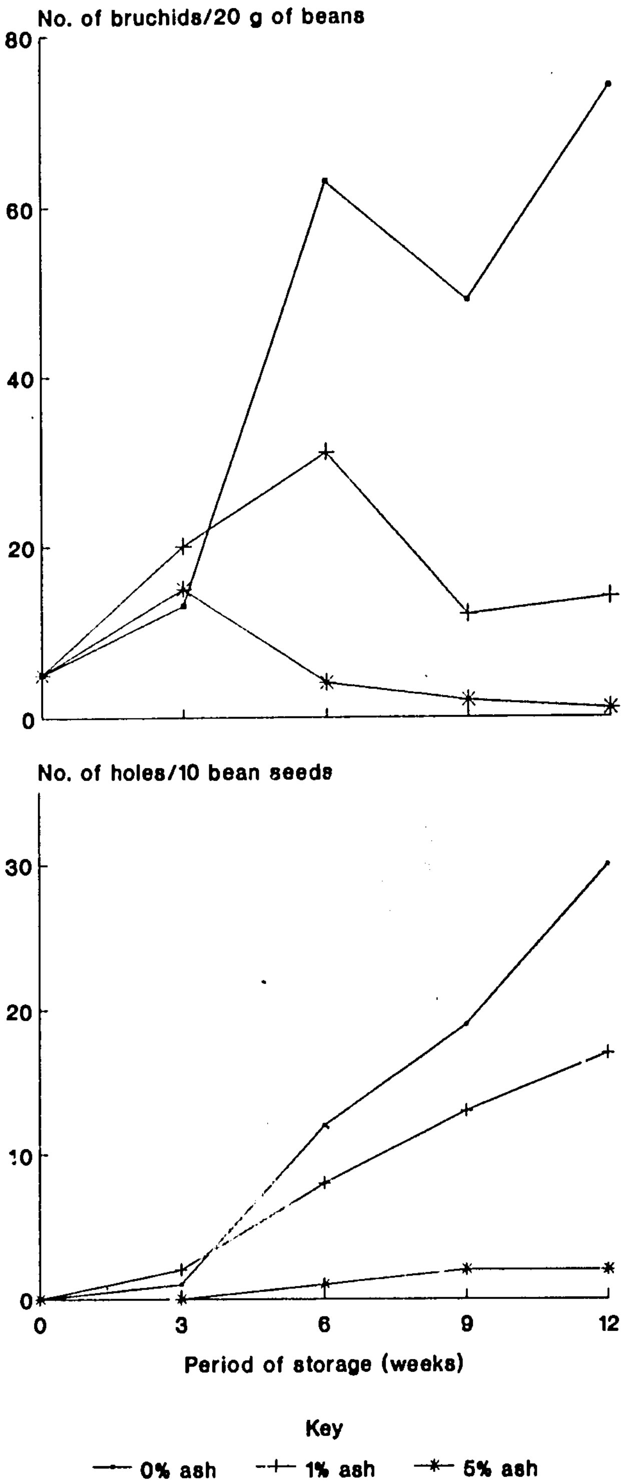
Five newly mated pairs of bruchids, selected from a bruchid colony, were introduced into glass vials containing 20 g of treated seeds. At 30 days and thereafter every three weeks for three months, bruchid adults (dead and alive) in each vial were counted and numbers of holes were recorded in ten seeds selected at random. On each occasion, the seed samples and live insects were returned to the vials. At the end of the storage period, the weights of beans were recorded and percentage losses in weight calculated.

Results

The numbers of bruchids/20 g seeds and holes/10 seeds were most at 0% ash and least in 5% ash, with 1% ash intermediate (Figure 1).

There were marked differences in population growth of bruchids among ash concentrations. At 0% ash, bruchid numbers were still increasing at the end of 12 weeks. At 1% ash, bruchid numbers peaked at six weeks and then

Figure 1. Effects of ash levels on populations and damage by A. obtectus.



decreased. At 5% ash, bruchid numbers peaked during the third week and then decreased. Losses in weight of beans in store also decreased with increasing ash concentration, from 12.9% at 0% ash to 1.9% at 5% ash with 1% ash intermediate (6.5%).

At 12 weeks, Kanyebwa (40 adults/20 g seed) harboured significantly (P = 0.05) more bruchids then Nambale (19 adults/20 g) and Haricot (15 adults/20 g) (Figure 2). There were also significantly (P = 0.01) more holes in seeds of Kanyebwa than in seeds of Nambale and Haricot, reflected in losses in weight of 12.8 (Kanyebwa), 4.7 (Nambale) and 3.8% (Haricot).

There were significant interactions between ash concentrations and cultivars for all three parameters, differences between Kanyebwa and the other cultivars decreasing as ash concentration increased so that, at ash concentrations of 5%, there were no differences among cultivars.

Discussion

The roles of both ash and cultivars in protecting bean seeds against bruchids have been clearly demonstrated. After 12 weeks in store, bean seeds that were not dressed with ash had already suffered appreciable losses in weight (12.8% in the most susceptible cultivar), which were still increasing. This compares with the losses observed by Byaruhanga (1973) after storing for 24 weeks. Most interesting was the reduction in weight loss to 2% by an ash concentration of only 5%, equivalent to 50 g ash/kg of beans. Adding small quantities of ash to beans and other products appears to offer an effective, cheap and highly practical means of protection against bruchids during storage.

Nambale and Haricot suffered significantly less damage due to bruchids than Kanyebwa. This difference was perhaps due to differences in testa hardness, as Nambale types are not liked by farmers because of their hard testa and long cooking time (Sengooba, 1987). In the short term, it may therefore be advisable to recommend farmers to use Kanyebwa, which they prefer, with the addition of 5% or more ash. Meanwhile, research should continue to develop cultivars which are both acceptable to farmers and resistant to bruchids. Although the present results are preliminary in nature, they suggest that ash and resistant cultivars can play important roles in protecting beans against bean bruchids. What ought to be done therefore includes:

i. identifying acceptable formulations and application rates which could be recommended to farmers and processors; and

ii. seeking other traditional protectants which may be combined with ash to increase efficacy and efficiency.

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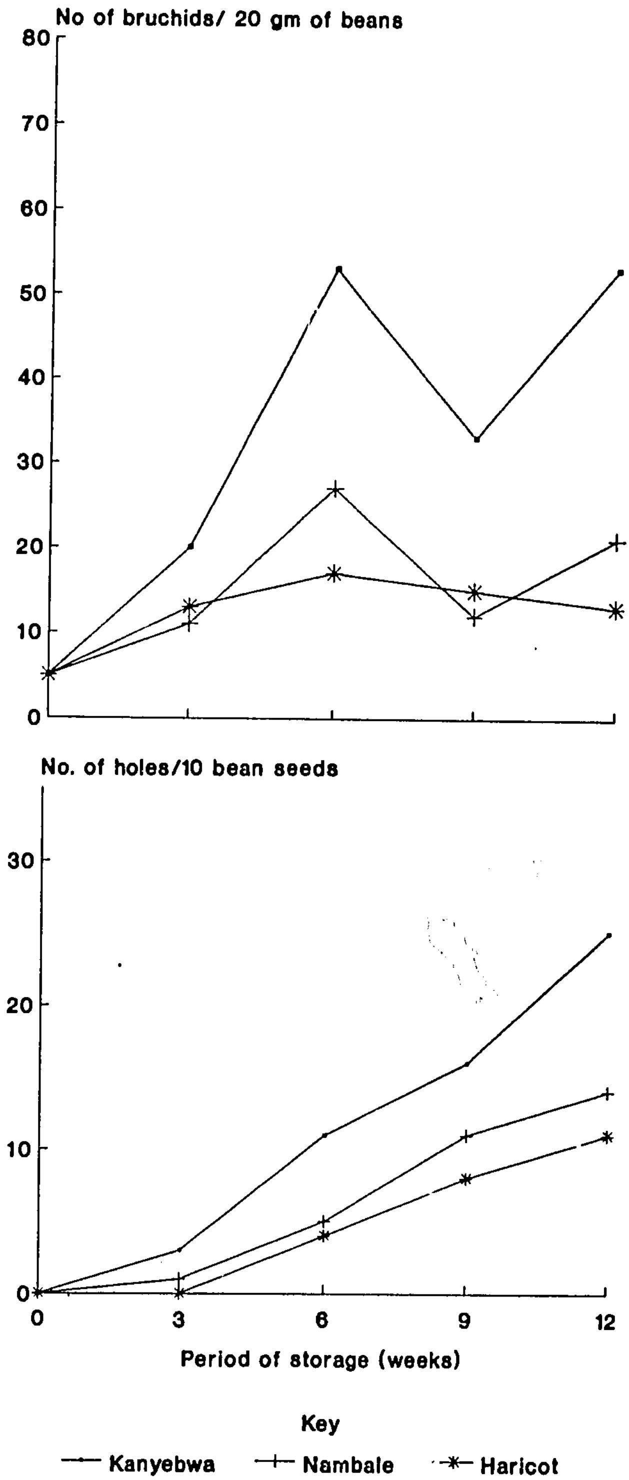
Figure 2. Effects of bean cultivars on populations and damage by A. obtectus.



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Beanfly Infestation on Common Bean (Phaseolus vulgaris L.) in Kenya.

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Abstract

The population patterns of eggs, larvae and puparia on bean plants and leaf punctures made by adults were investigated during cropping (March-July; October-January) and noncropping (July-October) seasons at two sites in Kenya. Bean grown in noncropping seasons had more leaf punctures, eggs, larvae and puparia than bean grown in cropping seasons. Bean sown in noncropping seasons attracted unusually high beanfly populations from surrounding weeds as well as previous crops. Under field conditions, the beanfly species, Ophiomyia spencerella Greathead and O. phaseoli Tryon, infested bean plants in all seasons. Both species normally oviposited in punctures on the leaves but O. spencerella also oviposited in the stems of bean seedlings.

Introduction

Agromyzid beanflies are widely distributed seedling pests of bean in eastern and southern Africa, Asia and Australia (Singh and van Emden, 1979). Heavy losses of common bean due to beanflies have been reported from eastern Africa (Wallace, 1939, 1941; Swaine, 1968; Schonherr and Mbugua, 1976; Njuguna *et al.*, 1981; Omunyin *et al.*, 1984). The seasonality of beanflies in eastern Africa has also been reported by Wallace (1941), Walker (1960), Swaine (1968), Greathead (1968), Okinda (1979), Mueke (1979) and Kibata (1980). They are present in bean growing areas of Kenya throughout the year, though levels of infestation fluctuate. In this study, levels of beanfly infestation were assessed during cropping and noncropping seasons on a local susceptible cultivar of *P. vulgaris*.

Materials and Methods

The experiments were conducted at the National Agricultural Laboratories (NAL) and Kabete Campus Field Station, both near Nairobi. Both locations are at an altitude of about 1700 masl and have well-drained, very deep, dark reddish brown to dark red friable clay (Humic Nitosol) soils. The climate is characterized by alternating dry and wet seasons and absence of large seasonal changes in temperature. The precipitation pattern is bimodal with one long rainy season from mid-March to May and a short rainy season from mid-October to December. The period from June to October is cool, rather cloudy and almost dry, while the warmest time of the year is from mid-December to mid-March. The mean air temperature is 18°C and mean soil temperature 22°C. The ecological zone is dry sub-humid to semi-humid.

The bean cultivar, GLP 2 (Rose Coco), was grown in plots of 21.5 x 5 m, with an inter-row spacing of 50 cm and within row spacing of 10 cm. DAP fertilizer was applied at sowing at a rate of 200 kg/ha. The crop was weeded two to three times per season. Neither insecticide nor fungicide was applied in the experimental plot. The bean seedlings were left to natural beanfly infestation. Sampling started seven days after emergence of the seedlings and continued at weekly intervals during the growing period of the crop. One plant was randomly sampled from each of the 44 rows of every plot. Data recorded were: the number of beanfly punctures in the leaves; the number of eggs and first instar larvae obtained by dissecting leaf punctures under a binocular microscope; the number of eggs obtained by dissecting the beanfly punctures in the stems under a binocular microscope; the number of larvae and puparia obtained by dissecting the stems; and the number of dead plants due to beanfly attack. Beanfly species were identified from the colour of their puparia. The puparia of *Ophiomyia spencerella* Greathead are glossy black and those of *O. phaseoli* Tryon have black apices and yellow-brown intermediate segments.

The experiments were conducted for four seasons. The locations, sowing and first sampling dates and season codes which will be used in the text are listed in Table 1.

Table 1. Dates of emergence and sampling for beanflies at Kabete and NAL during 1984 and 1985.

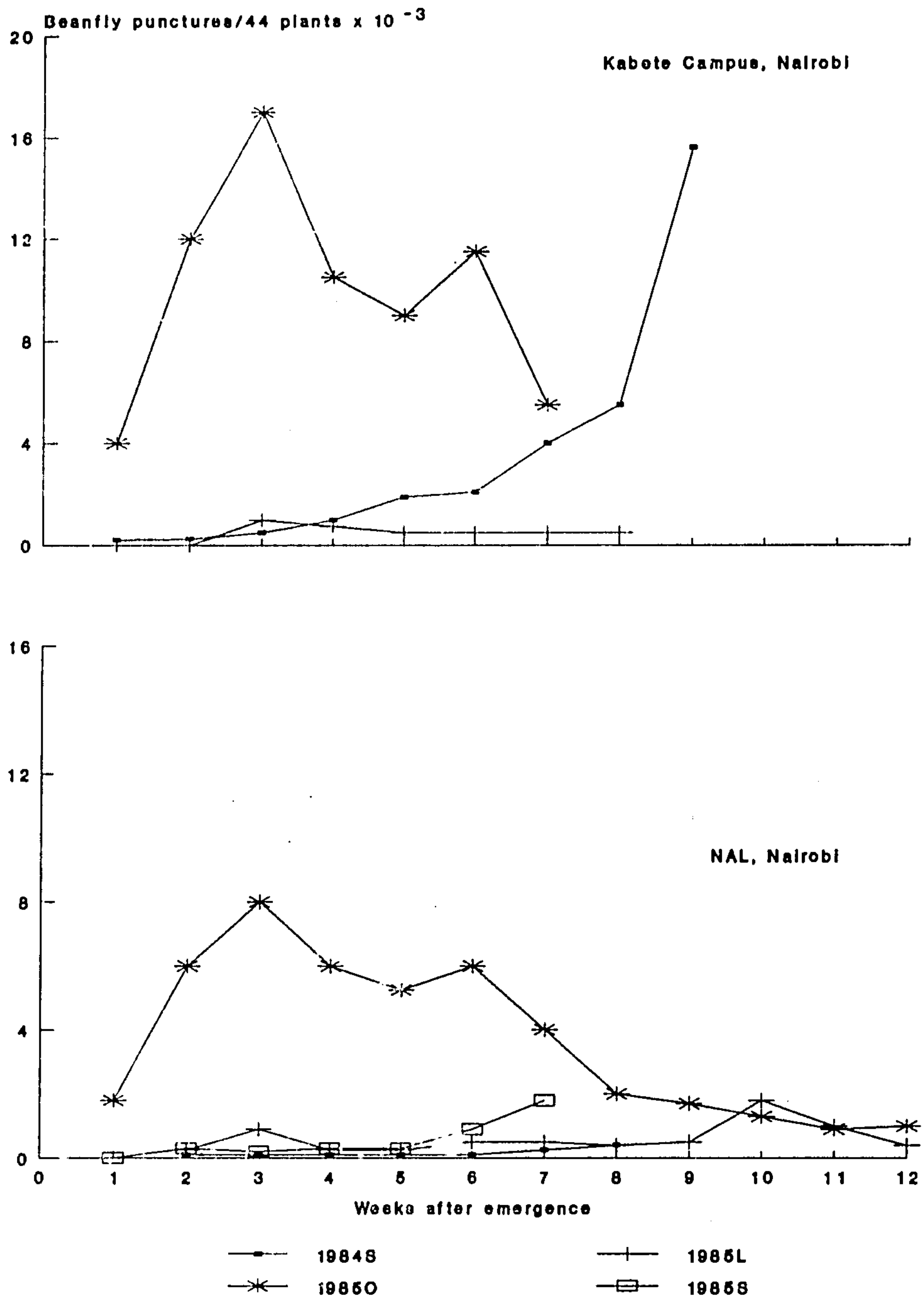
Season	Code	Site	Emergence	First sampling
Short rains, 1984 (October-January)	1984S	NAL	23 October	9 November
		Kabete	8 November	16 November
Long rains, 1985 (April-July)	1985L	NAL	1 April	11 April
		Kabete	29 March	9 April
Off-season, 1985 (July-October)	1985D	NAL	11 July	16 July
		Kabete	2 July	9 July
Short rains, 1985 (November-February)	1985S	NAL	16 November	23 November

In 1984S, there was heavy rainfall in October and November and light rainfall in December and January, when it was found necessary to irrigate the crop. During 1985L, there was heavy rainfall in April and May, but light rainfall in June and July. The rains were adequate and therefore the bean crop was not irrigated. The crop was irrigated throughout the growing period during 1985D. During 1985S, there was sufficient rainfall in October and November but the crop was irrigated during the months of December and January because rainfall was inadequate.

Results

Adult beanflies punctured the leaves of bean plants at the base and edges of the lamina with the base of the lamina the preferred site. Leaf puncturing occurred immediately after plant emergence and continued throughout the season (Figure 1). Accurate estimation of numbers of leaf punctures was possible

Figure 1. Numbers of beanfly punctures in leaves of bean plants.



within the first four weeks of beanfly attack, before punctures had dried and coalesced. During 1985D, leaf punctures were numerous at both sites during the early stages of growth. Beanfly leaf punctures were fewer in the other seasons except in 1984S, when there was a sharp increase in numbers of punctures in the latter part of the season at NAL.

Eggs were deposited in leaves immediately after plant emergence and oviposition continued throughout the season (Figure 2). They were found inserted singly in only a few of the leaf punctures located at the base of the leaf lamina. During both short rains seasons, the numbers of eggs laid in the leaf punctures were few immediately after emergence but increased later. During 1985L, oviposition was small throughout the season.

Eggs were not observed in the stems of young seedlings during 1984S, 1985S and 1985L. During 1985D, beanfly eggs were found in the stems and leaves of young bean seedlings and there was more oviposition in the seedling stage than towards maturity. Punctures in stems of seedlings were found both above and below ground level but eggs were laid mainly below ground level. Oviposition in stems occurred mainly during the two weeks after plant emergence, when there were more eggs in the stems than in the leaves. Later, the number of eggs in leaves exceeded those in stems.

Larvae pupated at the base of the stems in young bean plants and at the nodes of the stems of older plants. Larvae and pupae were observed on bean plants from three to four weeks after plant emergence in numbers related to the rate of egg-laying. During 1984S, 1985S and 1985L, there were few beanfly larvae and puparia in the early part of the season but numbers increased as the season advanced (Figure 3). There were more larvae and puparia in the early stages of growth of the crop and fewer in the later stages of crop growth during 1985L than during the two short rains seasons.

During 1985D, larvae were observed in the stems from one week after plant emergence. Total larvae and puparia in the plants reached a peak 3-4 weeks after plant emergence but thereafter were very few. The numbers of larvae and puparia in plants were greater in the early part of the season during 1985D than during the other seasons.

O. phaseoli and *O. spencerella* were both found infesting plants in the field. The population patterns of the two species are illustrated by the incidence of pupal stages in bean plants (Figure 4). *O. spencerella* puparia were found on plants three weeks after plant emergence while *O.phaseoli* puparia were found four weeks after plant emergence. During the two short rains seasons, populations of both species built up to the same level in later stages of growth at both sites. During 1985D and 1985L, the numbers of *O. spencerella* puparia were greater than those of *O. phaseoli*. Peak numbers of *O. spencerella* pupae during the two seasons occurred 5 weeks after plant emergence. The number of *O. spencerella* puparia in the plants were the same as the numbers of *O. phaseoli* puparia during 1984S and 1985S.

In terms of numbers of *O. spencerella* puparia in the plants seasons were ranked: 1985D>1984S>1985L>1985S. In terms of numbers of *O. phaseoli* puparia in the plants seasons were ranked: 1984S>1985D>1985S>1985L.

During 1984S and both long and short rains of 1985, beanfly infestations were not large enough to cause plant mortality. However, during 1985D, populations of *O. spencerella* were sufficiently large to kill plants, causing

Figure 2. Numbers of beanfly eggs oviposited in bean plants.

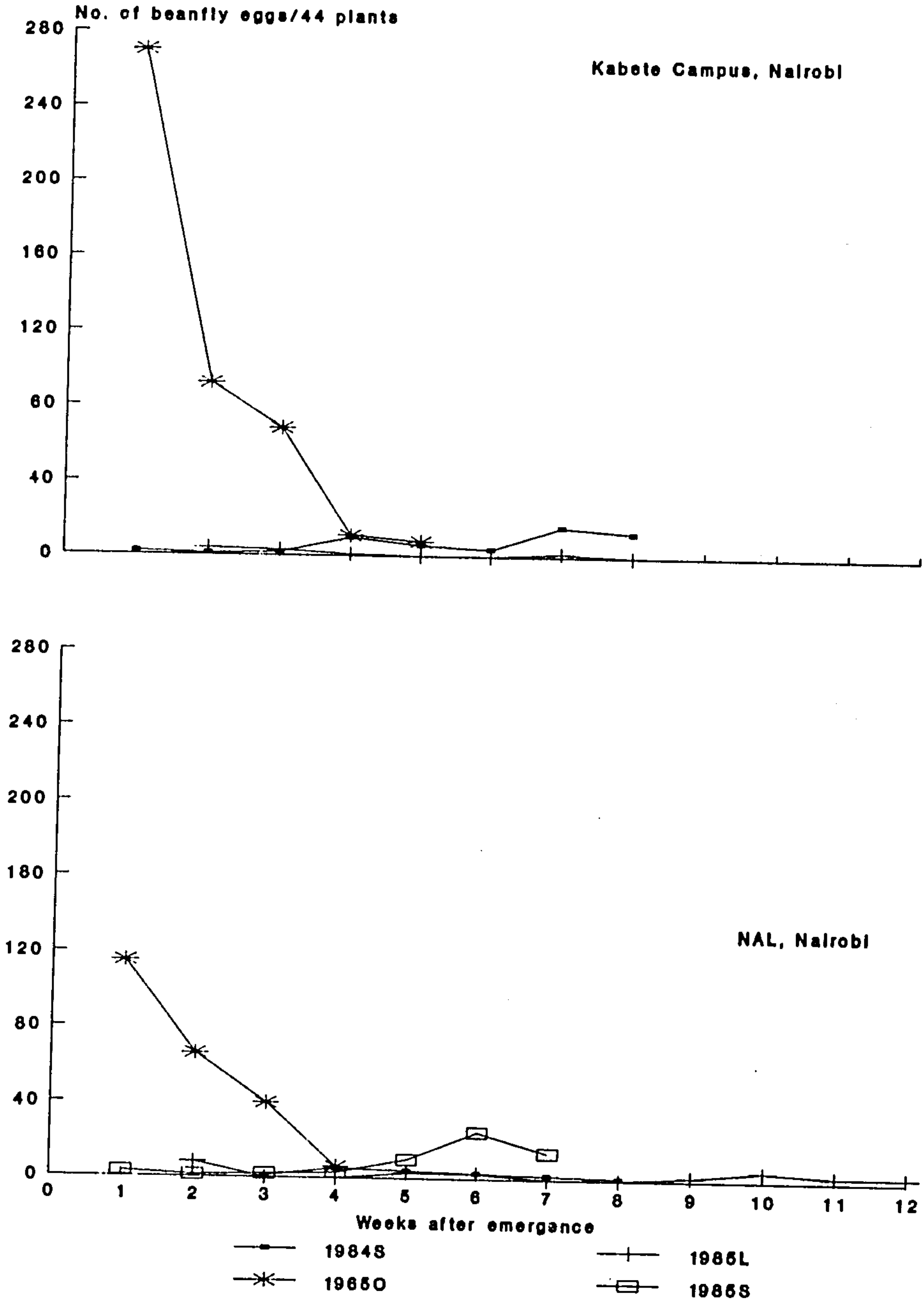


Figure 3. Number of beanfly larvae and pupae in bean plants.

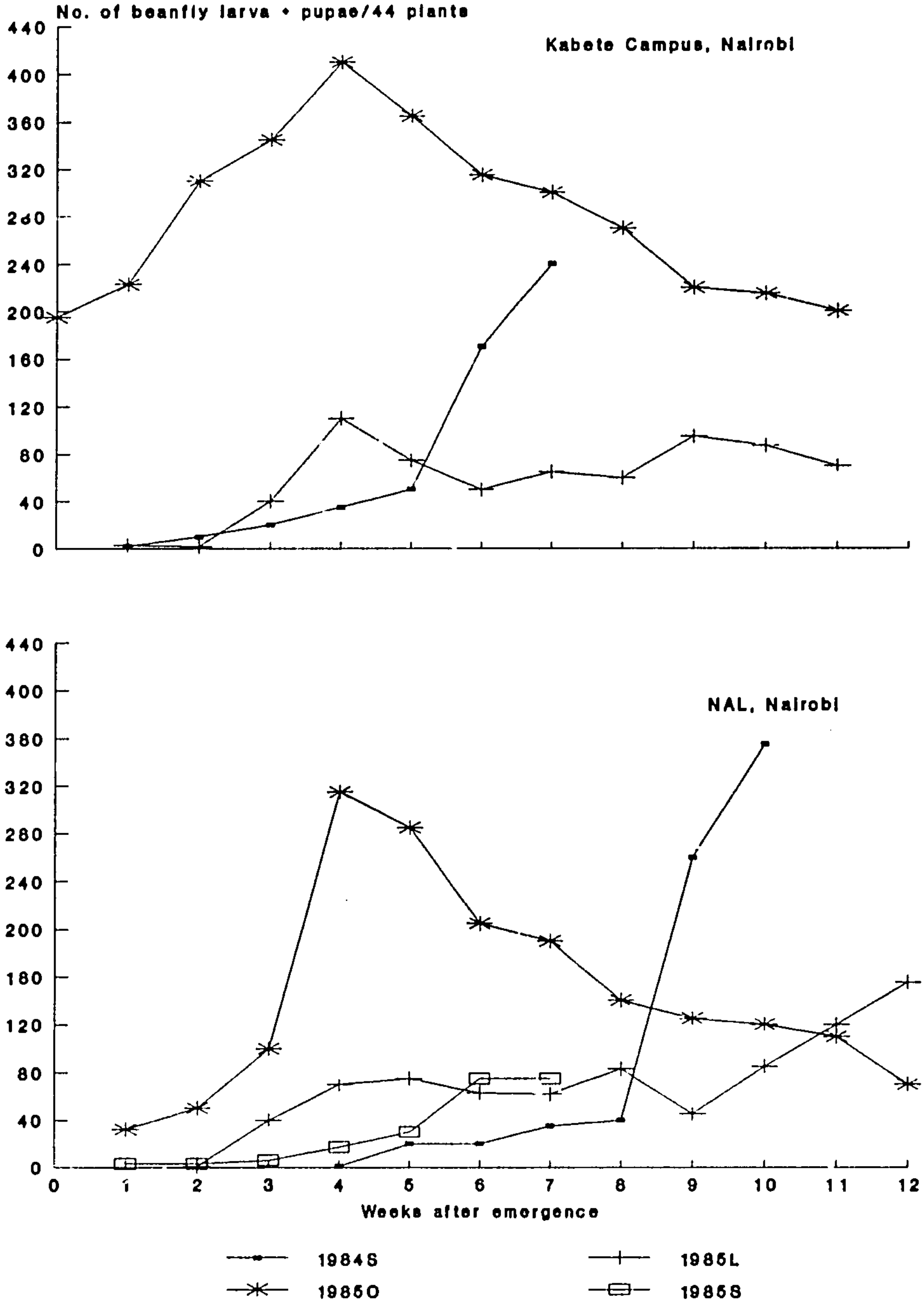
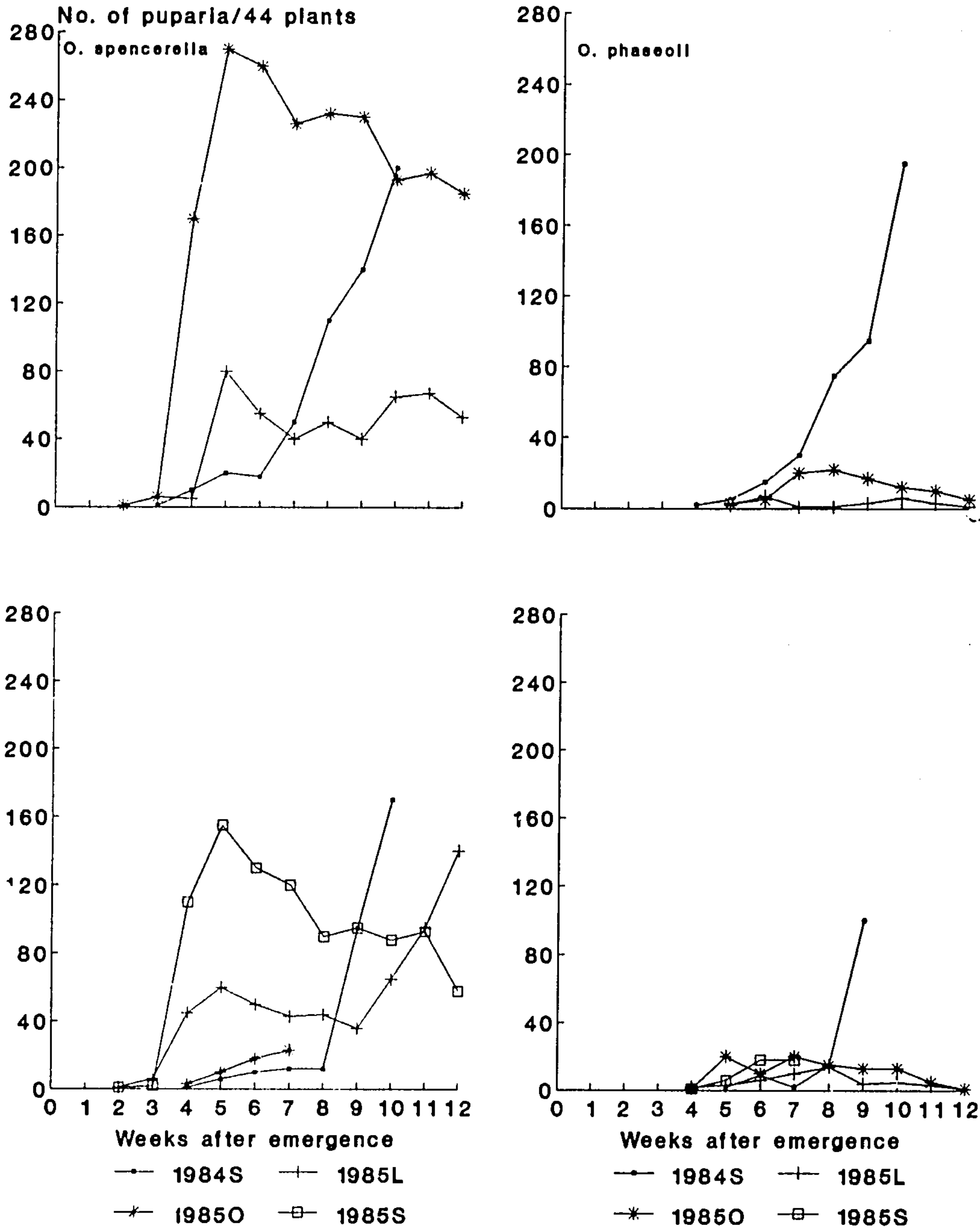


Figure 4. Numbers of O. spencerella and O. phaseoli puparia in bean plants



growth of calluses where larvae had pupated. Such damage resulted in withering of plants and stunting and yellowing of leaves. During 1985D, 53.2% of bean plants were killed at Kabete Campus Field Station and 42.6% at NAL, due mainly to *O. spencerella*. Mortality was first observed four weeks after plant emergence (Figure 5) and was complete five weeks after emergence. Plants that remained alive ten weeks after emergence continued to grow until the end of the season. Those that escaped or had little attack grew vigorously and produced heavy yields.

Discussion

Initial adult beanfly population was probably the main factor affecting the rate of leaf puncturing of bean plants. Okinda (1979) and Kibata (1980) assessed infestation from numbers of leaf punctures. With regard to *O. phaseoli*, they overestimated infestation because not all leaf punctures were used for oviposition. In contrast, they underestimated infestation by *O. spencerella*, which also oviposits in the stems. However, leaf punctures can be used as a relative index of the level of adult beanfly infestation within the first four weeks of beanfly attack.

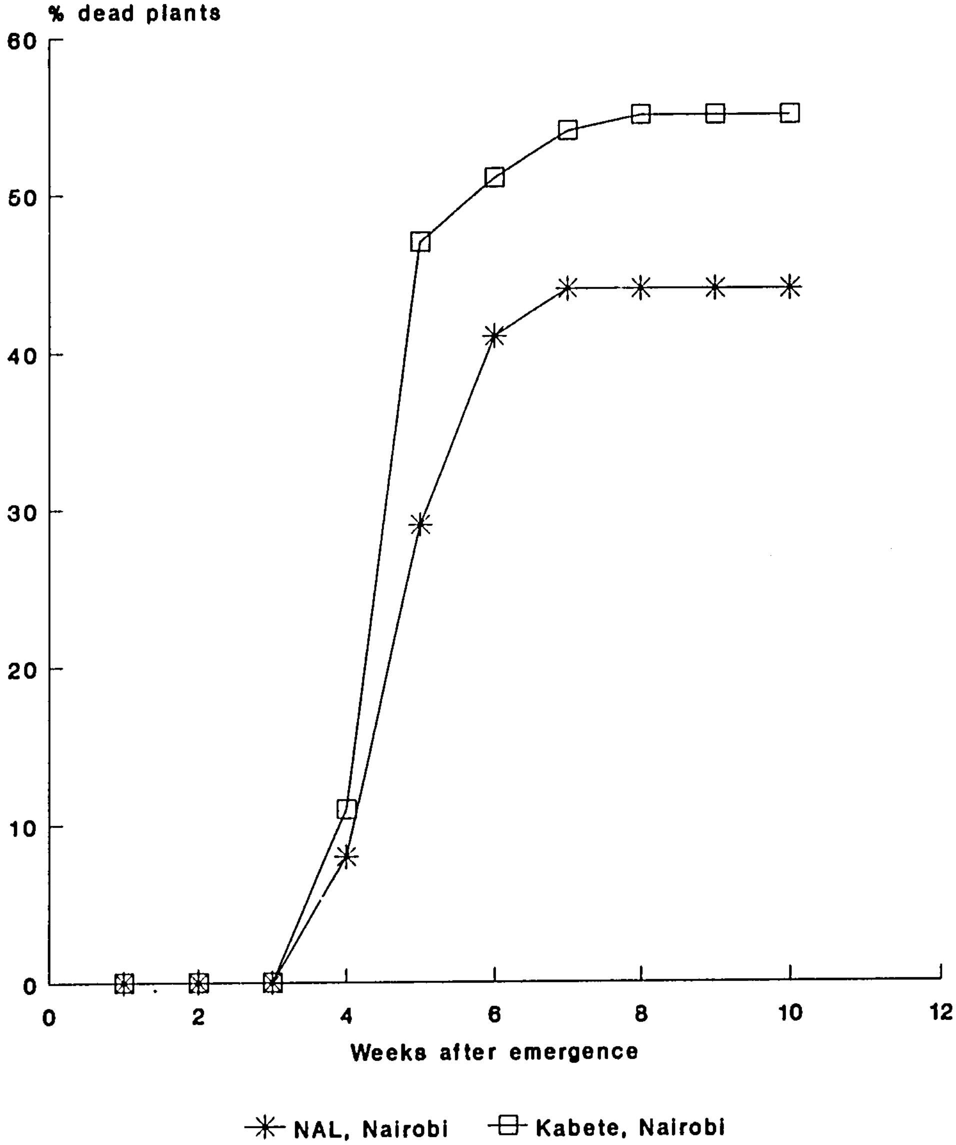
Wallace (1939) and Swaine (1968) in Tanzania stated that beanflies laid eggs only in leaf punctures. Walker (1960) in Tanzania reported that beanflies laid eggs only in the lower parts of the stems above the surface of the ground. The observations made during this study indicate that beanflies lay eggs in both leaves and stems during the off-season. .pn320

Greathead (1968) noted that oviposition in both stems and leaves indicated infestation of bean plants by at least two species of beanflies. He recorded that *O. spencerella* oviposited mainly in hypocotyls while *O. phaseoli* oviposited in leaves. Present observations indicate that whilst *O. spencerella* normally oviposits in leaves, like *O. phaseoli* it also oviposits in the stems of young bean seedlings when rainfall is light and the numbers of ovipositing adults are very large.

O. spencerella oviposits in stems above and below ground when oviposition sites are in great demand. In some cases, more eggs were laid in stems than in leaves, indicating that *O. spencerella* adults were more numerous and laid more eggs than *O. phaseoli* adults. Oviposition in the stems of bean plants, concentrated in the seedling stage, is more detrimental than oviposition in leaves because the lag period before susceptible parts of the bean plants (stem bases) are attacked must be shorter. No eggs were found in the stems of bean plants when rainfall was heavy, although oviposition occurred in the leaves. During the normal rainfall patterns, adults of *O. phaseoli* and *O. spencerella* oviposited in the leaves of bean plants throughout the growing period.

Second and third instar larvae and puparia in the stems were easier to count after dissecting because of their small size. The number of larvae plus puparia in the stems of bean plants is a good estimate of the relative population of beanflies in a field. Their numbers were much greater than the numbers of eggs recorded because of the difficulty of finding the latter. Okinda (1979) counted larvae and puparia in the stems of bean plants to estimate the degree of infestation. However, larvae of different species of beanfly are not easily differentiated because of their close morphological similarity. In this study, it has been possible to distinguish *O. spencerella*

Figure 5. Cumulative mean per cent dead plants caused by beanflies in a bean crop during 1985O



and *O. phaseoli* on the basis of the colour of the puparia. Walker (1960) in eastern Africa mentioned that *O. phaseoli* puparia were dark brown to black while Swaine (1968) observed that they were at first brown but later turned black. The present observations were similar to those of Greathead (1968) who described the puparia of *O. phaseoli* as yellowish brown with black apices and those of *O. spencerella* as shining black.

Earlier, the species in eastern Africa was considered to be *O. phaseoli* alone. In the present work, *O. phaseoli* and *O. spencerella* were both found infesting bean plants in the field. *O. centrosematis*, which was found in bean plants in Kenya by Greathead (1968), was not found in this study. This observation is in agreement with those of Okinda (1979) and Spencer (1985) who also identified only *O. phaseoli* and *O. spencerella* in the bean crop.

The presence and number of puparia can be very useful for population monitoring and host plant resistant studies because they can be accurately counted and easily identified to speci s level. *O. spencerella* puparia were observed in bean plants earlier than those of *O. phaseoli*. This may indicate that *O. spencerella* attacks younger plants (and therefore oviposits earlier) or develops faster than *O. phaseoli*. Relative numbers of the two species fluctuated among seasons. Generally one species predominated over the other. *O. spencerella* was numerous in seasons when there were prolonged wet conditions, while *O. phaseoli* was most numerous in dry conditions.

The extent of damage due to beanflies depends upon: the species; intensity of attack; population density; duration of the noncropping season; and the weather, which affects beanfly populations. However, each species can reach high population levels and cause serious damage in any season depending on the initial infestation of the bean plants and prevailing environmental conditions. Infestations of beans sown at the onset of the long or short rains were insufficient to seriously debilitate or kill bean plants. The generalization of Wallace (1941), Swaine (1968), Okinda (1979) and Kibata (1980) that beanflies cause serious losses during the short rains in eastern Africa can only be true when there is very little rain at the beginning of the season and a short noncropping season prior to the short rains allowing high initial beanfly infestation. Otherwise, the initial *O. spencerella* attack will not be enough to kill the plants and subsequent *O. phaseoli* infestation insufficient to reduce yields. Death of bean seedlings due to *O. spencerella* was observed when beans were sown just before the harvest of the previous crop, outside the rainfall pattern of the area, so there was no closed season.

Irrigation during the growing period did not reduce beanfly damage. In this situation, initial attack by *O. spencerella* was sufficient to kill bean seedlings. Plants which recovered from *O. spencerella* attack grew vigorously, probably because of less compe tion for space and soil nutrients. Infestation by *O. phaseoli* occurred mainly later in the season. The nature of attack of *O. phaseoli*, in old plants, led to poor pod and seed formation.

Acknowledgements

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Effects of Environment and Location on the Species Composition and Populations of Beanflies (Ophiomyia spp. Diptera, Agromyzidae) in Tanzania.

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Abstract

Beanflies (Ophiomyia spp. Diptera: Agromyzidae) species composition and temporal change in populations were studied at five locations during the long rains of 1988 and 1989. O. spencerella was the predominant species dissected from bean plants at all locations. O. phaseoli was always present but in relatively low numbers. In high altitude locations (more than 1,400 masl), beanfly populations consisted almost entirely of O. spencerella. In 1988, there was a reversal of species dominance in the low and medium altitude locations, with O. phaseoli being the dominant species early in the season. Beanfly infestation was low during periods of heavy rain but increased sharply with the cessation of rains.

Introduction

Beanflies (*Ophiomyia* spp.) are considered the most important insect pests of bean in Africa (Wallace, 1939; Greathead, 1969). Three species are recognised; *O. phaseoli*, *O. spencerella* and *O. centrosematis*, but the literature suggests there has been considerable confusion among the species (Allen and Smithson 1986). With increasing research being devoted in Africa to common bean, recent studies have emphasized the biology of beanflies and there are now indications that the ecology of the species may be distinct. Limited information suggests that *O. phaseoli* is more often dominant in warmer environments, at lower elevations, whereas *O. spencerella* dominates at higher altitudes; *O. centrosematis* appears to be much less abundant than the other two species (Irving, 1986; Autrique, 1988). Furthermore, at a single site, there can be strong reversals in species dominance during the course of a single season. No such studies have been conducted previously in Tanzania. The purpose of this study was to determine the distribution of beanfly species in five different ecological zones in Tanzania.

Materials and Methods

The sites used in this study during 1988 were: the Sokoine University of Agriculture (SUA) farm at Morogoro, 540 masl with a mean annual rainfall of 837 mm and annual temperature range of 16 to 33°C (mean 24.4°C); Lambo estate, near Moshi, 1,020 masl with a mean annual rainfall of 1,100 mm and annual temperature range between 21 and 26°C (mean 23.0°C); and Morningside, on the slopes of the Uluguru mountains above Morogoro, 1,440 masl with a mean annual rainfall of 2,330 mm and temperatures ranging between 15 and 23°C (mean 19°C).

Bean cultivars, TMO 125 (Selian Wonder), TMO 191 (Kabanima) and TMO 216

(G 1821) were used in 1988. There were three sowing dates at two weekly intervals at each location. The first were on 15 and 28 April and 15 May at SUA farm, Lambo and Morningside, respectively. Each plot was 6 rows, 5 m long. Seeds were sown singly 10 cm apart within rows. Beginning two weeks after plant emergence, 20 plants per plot were randomly selected and uprooted each week for four weeks. They were dissected and pupae and larvae were removed and counted. Following descriptions by Greathead (1969) and Spencer (1973), the pupae were sorted by species and their numbers were recorded. The pupae were kept for adult emergence and males were dissected and aedeagal characters used to confirm species identity.

In 1989, the sites were Lambo, Selian, Arusha (1,387 masl) and Mabughai, near Lushoto (1,560 masl). Bean cultivar, Lyamungu 85 was sown on five different dates at three weekly intervals starting 30 and 31 March and 7 April at Mabughai, Selian and Lambo, respectively. At four and six weeks after emergence, ten plants were selected at random from each plot and analyzed for beanflies as above. In both studies, the population of beanfly species found in each sowing at each site were used to determine temporal changes in the beanfly species populations during the growing season.

Available weather data for the periods of study were obtained from nearby meteorological stations and were used to relate environmental factors to species dominance.

Results and Discussion

Beanfly Species Dominance

Two beanfly species, *O. phaseoli* and *O. spencerella*, were found infesting bean plants at all five locations. In both years and in nearly all locations, *O. spencerella* was the dominant species accounting for nearly half of the beanfly population at Lambo in 1988 to nearly 94% at Morningside in 1988 and almost all at Mabughai in 1989 (Table 1).

Table 1. Beanfly Species Composition (Percentages of Total Local Populations) at Five Locations in Tanzania in 1988 and 1989.

Beanfly species	1988 SUA	1988 Lambo	1988 Morning-side	1989 Lambo	1989 Selian	1989 Mabughai
O. phaseoli	20.6	50.2	5.8	12.8	12.4	0.7
O. spencerella	79.4	49.8	94.2	87.2	87.6	99.3

Beanfly Population Dynamics

In 1988, there was a reversal of beanfly species dominance in relation to time of sowing at Lambo and SUA. *O. phaseoli* was the dominant species in the first sown crop but, by the second and third times of sowing, numbers of *O.*

spencerella had surpassed those of *O. phaseoli*. At Morningside, the populations of the two beanfly species were almost static, with *O. spencerella* dominating throughout (Figure 1).

In 1989, beanfly populations increased with delay in sowing, and peaked sharply during the fourth sowing date (early June) in all locations (Figure 2). In all three locations, *O. spancerella* populations were more dynamic and increased as the season progressed. *O. phaseoli* populations fluctuated within a narrow range (0-10 pupae/ten plants).

The trends in beanfly species dominance appear to be related to altitude, temperature and rainfall (Figure 3). The sharp rises in beanfly populations at Lambo and Selian in 1989 corresponded with the cessation of rains (Figure 3b). This phenomenon has also been observed with *O. phaseoli* populations in Thailand (Pipithsangchan and Sittisak, 1985). At Morningside, *O. spencerella* was the dominant species in both seasons, *O. phaseoli* forming less than 6% of the entire beanfly population. The proportion of *O. spencerella*, declined with decreasing altitude and increasing temperature. This trend has been reported also in Burundi by Autrique (1989) where *O. spencerella* dominance declined from 100% in Gisozi (altitude 2,100 masl) to 47% in Imbo (850 masl).

Reversals in beanfly species dominance in a single location have also been observed in Burundi (Autrique 1989) and Zambia (Irving 1986) in locations where two or more beanfly species occur together. In Zambia, Irving related the reversals to temperature.

This kind of information is very useful in site selection and timing of sowing for beanfly resistance screening. Nurseries can be screened against two different species if their population patterns are well enough known.

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Figure 1. Beanfly species dominance in relation to sowing dates during the long rainy season of 1988.

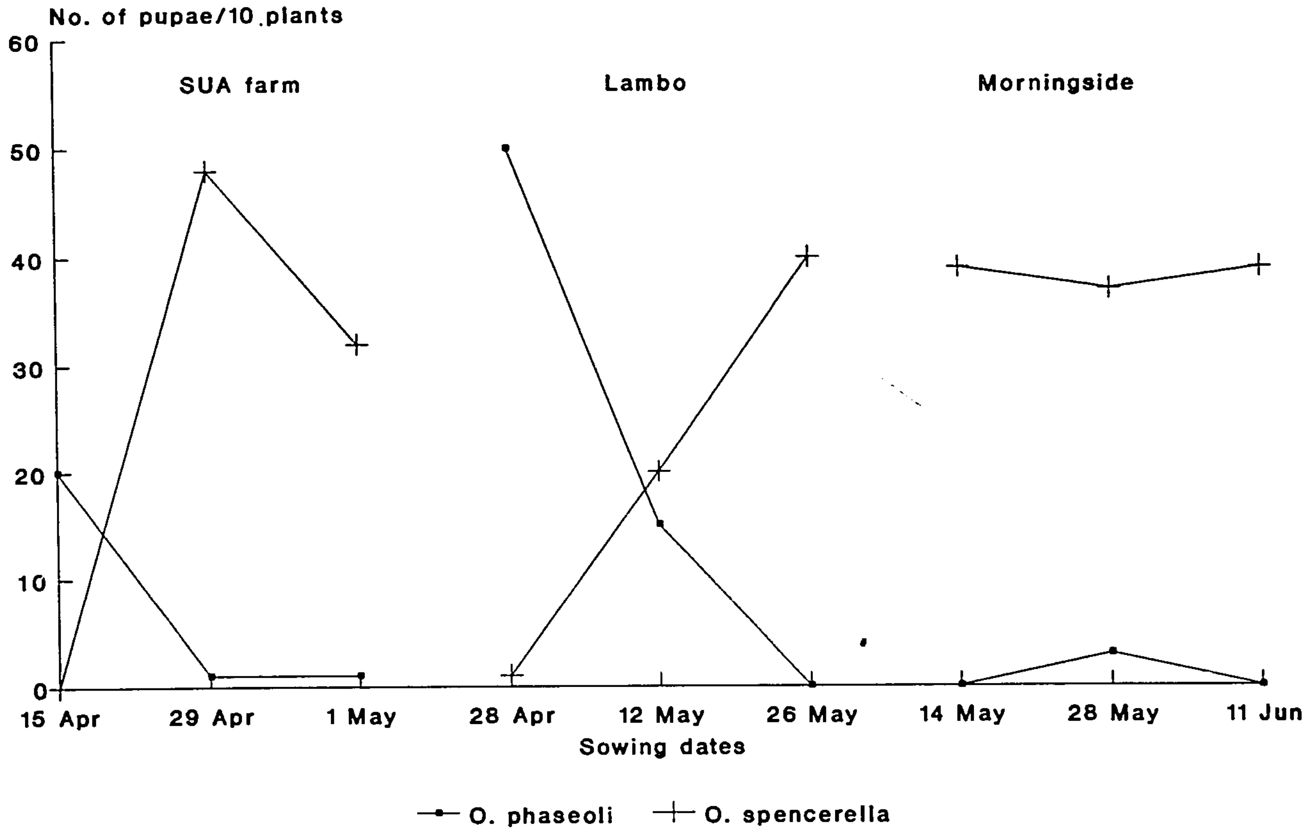


Figure 2: Beanfly population dynamics during the long rainy season of 1989.

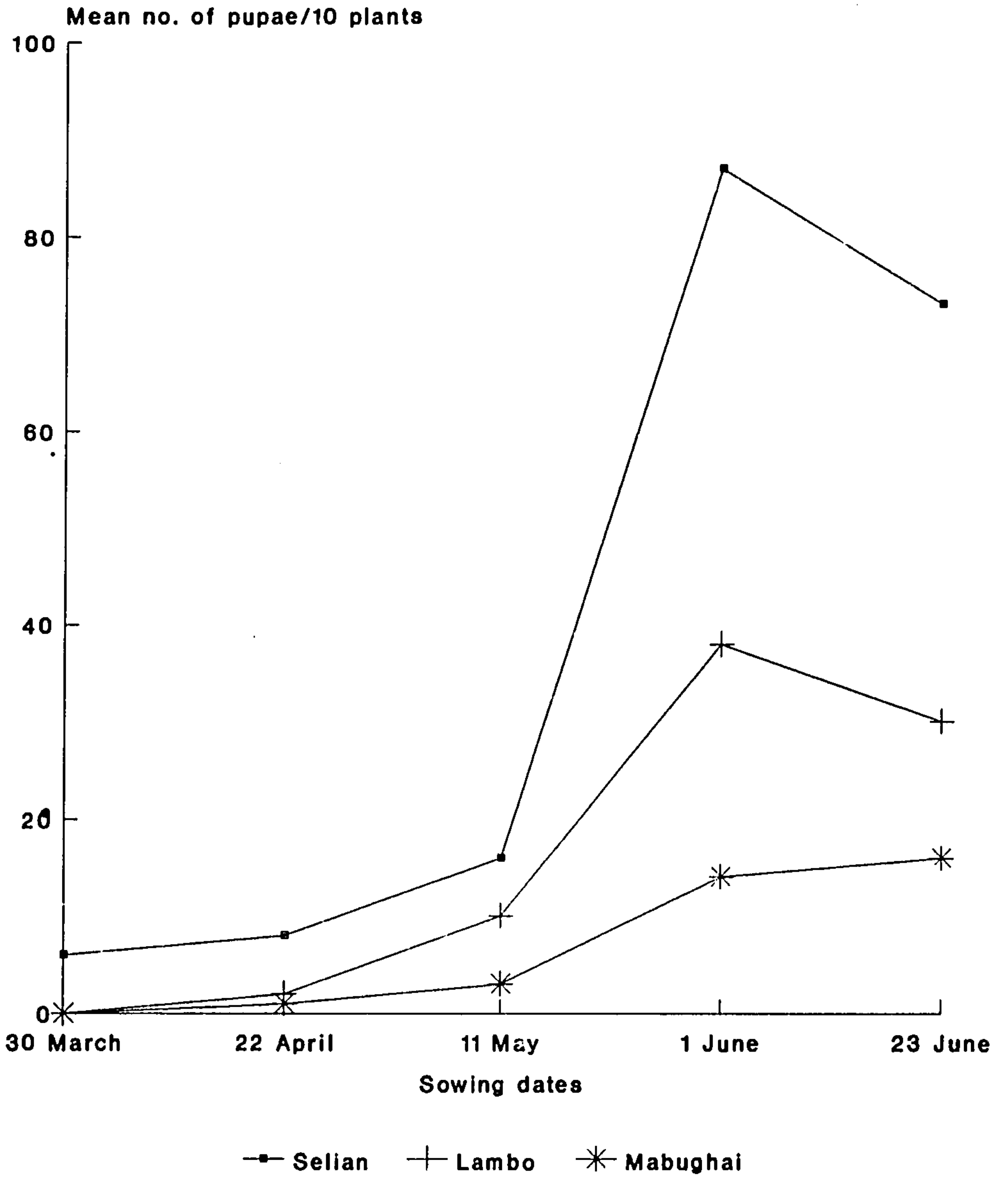
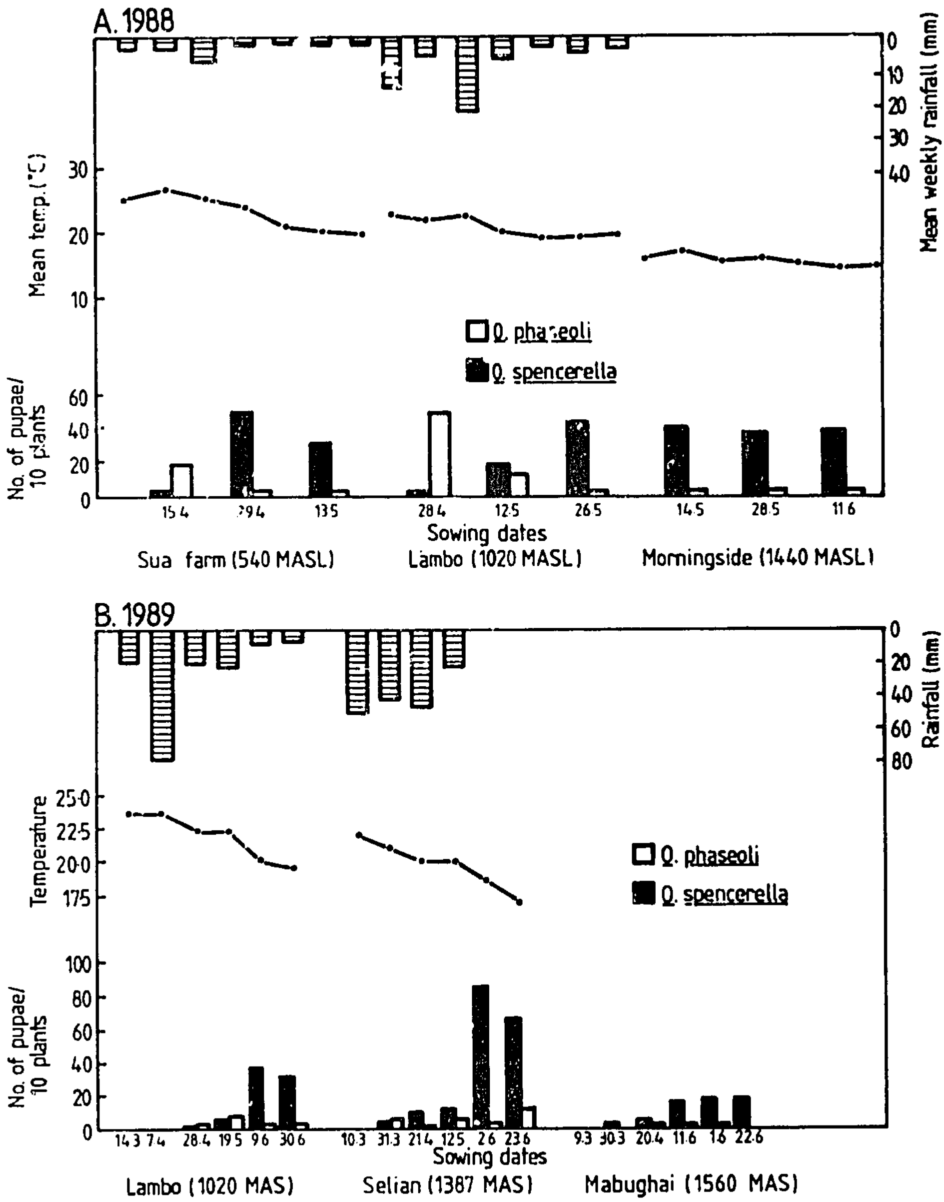


Figure 3. Beanfly Species Dominance in Relation to Rainfall, Temperature and Altitude at SUA farm, Lambo, Selian, Morningside and Mabughai During the Long Rainy Season of 1988 and 1989.



CIAT'S Strategy for Bean Entomology in Africa

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Abstract

Various collaborative research networks have been set up among bean entomologists in Africa. Among these are networks to study the biology and ecology of beanflies, aphids and bruchids and to develop management strategies for them. Studies of beanflies have identified relationships between ecologies and species composition as well as lines resistant to different species. Further work is under way to reconfirm resistance in different environments and to examine the potential for resistance to more than one species.

Introduction

Bean yields in Africa range between 200 and 1000 kg/ha (Londono *et al.*, 1980). Apart from infertile soils and poor management practices, pests and diseases reduce yields. A wide range of pests attacks beans during the various growth stages of the crop. They attack every part of the bean plant. The damage they cause includes defoliation, stem and pod tunnelling and removal of floral parts. The damage leads to poor plant growth, plant mortality and loss in pod yield and quality.

Losses due to insect pests of beans in Africa have been estimated in different parts of the continent. They range from slight to near complete loss (Table 1). Current recommended strategies to control bean pests rely heavily on insecticides. Such insecticides are very often unavailable to the resource poor smallholder who grows over 80% of food beans in Africa.

There is need therefore to explore alternatives to this form of bean pest control. CIAT emphasizes the development and use of insect resistant cultivars, supplemented sometimes by safe biological control strategies. Faster progress in this effort will be made through collaboration. CIAT's strategy therefore is to collaborate with national research programmes, through research networks, to solve the common pest problems that constrain bean production in Africa.

Setting Priorities in Bean Entomology Research in Africa

Because of our limited resources, there is need for well focused objectives and research priorities to maximize cost efficiency. For this purpose, a meeting of entomologists working on bean in Africa was held in August 1989 to:

1. review the current status of research in bean entomology;

2. identify common problems, set priorities for research and find solutions to them;

Table 1. Bean Yield Losses Attributed to Insect Pests in Africa.

Pest	Yield loss (%)	Country	Source
Foliar beetles (*Ootheca* spp.)	18-31	Tanzania	Karel and Rweyemamu (1984)
Aphids (*Aphis* spp.)	50	Burundi	Autrique *et al.* (1985)
	37	Tanzania	Swaine (1969)
	90	Uganda	Nyiira (1978)
Beanfly (*Ophiomyia* spp.)	50-100	Burundi	Autrique (1985, 1989)
	30-100	Kenya	De Lima (1983)
	30-100	Tanzania	Wallace (1939)
			Karel and Mattee (1986)
	100	Uganda	Greathead (1968)
	50-100	Zimbabwe	Taylor (1958)
Pod borers (*Heliothis armigera*,	15-25	Kenya	De Lima (1983)
Maruca testulalis)	33-53	Tanzania	Karel (1985)
Bruchids (*Zabrotes subfasciatus*,	73	Kenya	De Lima (1983)
Acanthoscelides obtectus)	23	Uganda	Rubaihayo *et al.* (1981)

3. determine areas of research among the priority pests; and,

4. develop collaborative research networks to tackle the common problems.

The priority pests were identified to be: beanflies (*Ophiomyia* spp.), aphids (*Aphis* spp.) and the bruchids, *Acanthoscelides obtectus* (Say) and *Zabrotes subfasciatus* (Boheman). The research network cooperators focus on different aspects of a given problem but operate in such a way that their objectives and results mesh to form a consolidated strategy.

Preliminary Results

Beanflies

Work on beanflies is one of the oldest associated with CIAT in the region. The focus has been on ecology and host plant resistance. In 1986, over 1200 germplasm accessions representative of the *Phaseolus vulgaris* germplasm collection at CIAT were screened against the prevailing beanfly species in Ethiopia by entomologists from the Agricultural Research Institute (ARI) and CIAT staff. Fourteen accessions with moderate to high levels of resistance were identified.

At about the same time, germplasm collections were screened by scientists in Burundi and Zambia in cooperation with CIAT. Two accessions (a local landrace, Ikinimba) and a CIAT breeding line (BAT 1373) were selected as resistant in Burundi. In Zambia three accessions (a Ugandan landrace, Gayaza 8 = ZPv 292) and two CIAT breeding lines (A 74 and BAT 1500) were selected as resistant.

Studies of beanfly ecology suggested a relationship between beanfly species composition, altitude and temperature. In Burundi beanfly species encountered at high altitudes (2,100 masl) were almost entirely *O. spencerella*. The proportion of *O. spencerella* in the population decreased with altitude (Autrique, 1989). At Msekera, Irving (1986) observed a reversal in beanfly species dominance as temperature decreased. This kind of information is very useful in site selection and timing of sowing of nurseries to screen for beanfly resistance.

The putative beanfly resistant lines (Table 2) have been composed for further evaluation at several locations, to reconfirm their resistance and to test for multiple resistance to the three beanfly species. Preliminary results confirm Ikinimba to be resistant to *O. spencerella* in Gisozi but susceptible to *O. phaseoli* in Shanhua (Taiwan). ZPv 292 was resistant to *O. phaseoli* in Shanhua but susceptible to *O. spencerella* in Gisozi. BAT 1383 was resistant to *O. spencerella* in Gisozi and tolerant to *O. phaseoli* in Shanhua. EMP 81 was reported to be resistant in Ethiopia where the dominant beanfly species is *O. phaseoli*. In Gisozi, EMP 81 was among the best four entries in all the parameters used for the evaluation of resistance.

The reactions of BAT 1373 and EMP 81 suggest multiple resistance to different beanfly species, while Ikinimba and ZPv 292 show specific resistance to *O. spencerella* and *O. phaseoli*, respectively. This encourages search for materials with similar or greater levels of resistance for use in breeding programmes.

Other collaborative research activities on beanfly include an on-farm survey of losses. Assessment of yield losses due to beanflies have generally been based on data from on-station trials. The objective of the present proposal is to study the situation in farmers' fields under farmers' own practices. Researchers in Zambia and Malawi have elected to participate in this survey and it is hoped that Kenya and Uganda will participate too. This will help generate data over a wide area in a short period of time.

Aphids

Preliminary results from Burundi and Zambia suggest that even though *Aphis fabae* is the only aphid that colonizes bean regularly in Africa, over 30 species are commonly found in yellow traps in bean fields. One of the principal objectives of the sub-project on aphids is therefore to:

- determine which aphid species among these act as vectors of BCMV;
- compare the relative efficiencies of transmission among these species; and
- determine differential transmission of different strains of the virus by different aphid species.

Table 2. Entries in the Beanfly Reconfirmatory Nursery

Line	Source	Other name	Country	Seed colour	Seed size
G 2005	Guatemala	PI 310739	Ethiopia	Black	S
G 2472	Mexico	PI 313343	Ethiopia	Black	S
G 3844	U.S.A.	I 1162	Ethiopia	White	M
G 5253	Brazil	BZL 1198	Ethiopia	Black	S
G 5773	Colombia	None	Ethiopia	Black	S
EMP 81	CIAT	None	Ethiopia	Black	S
Ikinimba	Burundi	None	Burundi	Black	S
BAT 1373	CIAT	IN17 X SEL72	Burundi	Black	S
A 74	CIAT	A30 X G4017	Zambia	Yellow	M
ZPV 292	Uganda	Gayaza 8	Zambia	Purple	M

Bruchids

The sub-project on bruchids examines small farmers' storage systems and losses associated with them. It will study also bean bruchid biology and ecology and develop strategies to improve storage efficiency on-farm.

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SUMMARY OF DISCUSSIONS

Pathology General

Both speakers who presented papers describing effectiveness of disease control with fungicides were questioned about the economics of fungicides for small scale bean producers. In Mauritius, farmers tend to spray regularly while in Kenya, fungicides are rarely applied to bean. Neither speaker presented data indicating whether or not the extra yields provided by fungicide use offset the costs of the fungicide. In the case of common bacterial blight (CBB), copper compounds did not effect any control. Possibly the pathogen harbours a plasmid that is able to detoxify copper compounds. The use of DNA probes to identify strains of CBB was questioned because of the expense; however, "cold probes" allow rapid identification of CBB in the field.

The issue of fungicide safety was raised. In Africa, some fungicides and other agricultural chemicals have been marketed which have been banned in western countries for human health reasons. Researchers were cautioned to check on the agricultural chemicals they recommend.

The feasibility of biological control of plant pathogens was discussed. None of the speakers had tried biological control methods although there are reports in the literature of successful biological control. In Israel, a technique called "solarization" was developed where polyethylene plastic sheets are spread over the soil, the soil heats up and some fungal, nematode and weed species germinate and die.

The results of the survey of seed transmitted fungi found in farmers' seed beans in Kenya may indicate that farmers can produce seed beans without having to purchase certified seed. In Colombia, "artisenal seed" farmer groups produce bean seeds at low cost. It was also pointed out that the seed samples were taken in only two districts after the short rains and the weather conditions of that growing season probably affected the fungal species composition in the seeds. Different results might have been obtained if sampling had occurred in other districts or after the long rains. Temperatures of the cultures in the growth chamber may have favoured genera such as *Fusarium*.

Cardona

Arcelins do not necessarily affect seed quality, specifically the cooking quality of bean seeds. Obviously seeds of some cultivars are difficult to cook. There are now about 120 lines combining presence of arcelin with different seed sizes and colours.

Silim

It appears that *Zabrotes* was introduced into Uganda mainly across Lake Victoria as seeds obtained from lake people were the only source of *Zabrotes*.

Kyamanywa

Future studies should examine the effects of ash particle size on the efficiency of weevil control. Since banana is widely grown in Uganda, its ash must be studied as another method of control.

Nderitu *et al.*

When farmers plant their bean early, say early March, there will be less damage due to beanflies but if bean is planted late, say in April, damage can be serious. This is true for Kenya, Tanzania and Zambia. No comparison is yet made of differences in damage in the long and short rains. Drought at planting has a tendency to enhance damage by beanflies. If there are large numbers of eggs, damage is greater.

Oree *et al.*

Temperature and rainfall are the most important climatic factors affecting the compositions and densities of beanfly populations. In warm temperatures *O. phaseoli* predominates while in cool temperatures and high altitudes *O. spencerella* is present in greater numbers. Other factors may also be involved.

Because *O. spencerella* oviposits on the stem and hypocotyl damage is relatively severe. *O. phaseoli* oviposits on the leaves. Damage is also affected by density of beanfly populations and bean cultivar.

Ampofo

Reversal of species dominance is a common phenomenon in insects but the cause is not well understood and requires detailed investigation.

On the BCMV/aphids relationship, it is suggested that aphid species of Latin America differ from those of Africa, which are more of colonizer types. Different aphid species may transmit mosaic and necrotic strains of BCMV, which may account for the rare occurrence of necrotic strains of BCMV in Latin America. This merits further study.

Entomology General

Bruchid resistant materials are now available at CIAT for distribution to national programmes.

The identities of the bruchid species present in Somalia are as yet unknown and there is a need to clarify the situation. As Bruchid taxonomy is now well understood, CIAT is willing to collaborate in such an investigation.

Bruchid resistant lines have now been exposed to bruchid populations over several seasons and locations without changes in their resistance levels. There is always danger of the development of new biotypes but, so far, there is no evidence that this has occurred. Arcelin, found in the cotyledons, has insecticidal action. The nature of its effect on bruchids requires further investigation.

For control of beanflies, emphasis should be given to seed treatment and adjusting planting patterns as in Malawi. In Malawi, ridging has been shown to enhance production of adventitious roots and plant recovery from beanfly attack.

There is no record of adverse effects of seed treatment with ash on seed viability.

Bean Diagnostic Surveys In Muranga and Kisii Districts of Kenya

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Abstract

The results of an informal diagnostic survey of Kisii and Muranga Districts during September and October 1989 are reported. Muranga District, in the Central Province of Kenya, has an agricultural potential of 180,800 ha, some 11,700 ha less than that for Kisii in Nyanza. In both districts, maize and bean are first and second in importance as food crops and are commonly grown in association in intercropping or relay cropping systems. There was less genetic diversity in Kisii (Bosongo Division) than in Muranga. In the former area, the predominant bean cultivar is similar to Rose Coco. Other types included Canadian Wonder and a small seeded climbing type of Rose Coco, now abandoned. About 75% of beans produced are sold. In Muranga, besides Rose Coco, available types include Canadian Wonder, Mwitemania and Red Haricot. Most farmers in both Kisii and Muranga use their own seed or purchase it locally. The main bean production constraints are diseases and pests; poor availability of labour; and poor soil fertility and drought in lower elevation areas during the short rains.

Introduction

Bean (*Phaseolus vulgaris* L.) is an important pulse in many countries where it constitutes a major source of protein in human diets. In Kenya, it is second only to maize as a food crop and grown on some 0.5 million ha annually, representing 6% of the country's agricultural land. Cultivation of the commodity is widespread in all agricultural areas but average yields are only 0.5-0.7 t/ha, hardly half the potential yield, in spite of recommendations of cultivars adapted to various agro-ecological zones, fertilizer and manure use and other agronomic practices years ago by the National Horticultural Research Centre, Thika (Anon., 1982; van Rheenen *et al.*, 1984).

Previous on-farm bean research in Kenya (Anon., 1982; Floor, 1984) and surveys in Eastern and Central Provinces and in Kisii (Zoebl, 1984; Malinga, pers. comm.) were initiated to understand the reasons for poor bean yields and the constraints to the adoption of new recommendations by farmers. Jaetzold and Schmidt (1983) too, provided very useful information on natural conditions and farm management in Kenya. However, little is known for example, about farmers' enterprise patterns and system trends as they relate to bean production. The purpose of this study was to understand farmers' bean production practices and techniques, determine the extent of adoption of new recommendations and identify key farmer problems.

Methodology

Diagnostic surveys were conducted in Kisii (Nyanza Province) and Muranga (Central Province) Districts. Background information was obtained from the relevant agricultural offices and an appropriate number of extension officers were called upon to facilitate contacts with farmers. In Kisii, a previous survey focusing on maize had been conducted in Kiamokoma area (Keumbu Division), at an altitude of 2,020 masl, therefore a lower altitude area (Bosongo Division) was preferred. Within each district, three distinct bean production zones were identified, located along gradients of decreasing elevation. In Kisii, these zones were tea, coffee and groundnuts while in Muranga they were tea, coffee and cotton. A total of at least forty farmers were interviewed. The questions directed to farmers sought to describe farm enterprises, crop production practices and constraints.

Results

General Description

Kisii District is a high potential area comprising some 192,500 ha of agricultural land with an average farm size of 1.8 ha. The district population is about 1.3 million with a density of 500-600 persons per km^2. Lying at 1,250-2,100 masl, the district is endowed with fertile well-drained soil and high rainfall. Bosongo Division, for example, at 1,500-1,900 masl, receives an average annual rainfall of 1,600-1,800 mm. Muranga District, with almost similar conditions, has 180,800 ha agricultural land, an average farm size of 1.2 ha and average annual rainfalls of 850 mm at lower altitudes and 2,700 mm at higher altitudes.

In both districts the major food crops include maize, bean potato, banana and millet. Table 1 shows home consumption of major foods produced on farm.

Farm Enterprises

In both Kisii (Bosongo Division) and Muranga, maize and bean are first and second in importance as food crops. Other food crops are Irish potato, cassava, fruits and vegetables. The main cash crops are tea, coffee and pyrethrum. At lower altitudes, cotton is to Muranga as groundnut is to Kisii. An important feature of Muranga is the growing of drought resistant pigeon pea.

Mixed cropping is common to both areas. Bean is grown in association with maize, fruits, such as avocado and banana, and vegetables, like tomato, cabbage and onion. Bean is more common in association than in pure bean stand. Bush bean types are preferred for associated cropping and chances are high that farmers like climbers more in Kisii than in Muranga. Further, relay cropping is practised more in Kisii than in Muranga. Maize and bean are planted in the same field but the latter are replaced at harvest by *wimbi*.

Table 1. Home Consumption of Major Food Produced on Farm.

	kg/year/household[a]		Cals./person/day	
Commodity	Kisii	Muranga	Kisii	Muranga
Maize	1279.5	1013	2062	1959.5
Bean	236	202	375	383
Irish potato	61.5	115	20.5	45
Sweet potato	29.5	5	10	3
Cabbage	12.5	197	1	24
Finger millet	67.5	0	46.2	0
Cooking banana	50	0	20	0

[a] average household sizes based on 1979 census, 10.25 for Kisii and 8.11 for Muranga

Source: Jaetzold and Schmidt (1983)

Animals are kept in most homes. These include cattle, goats, sheep and hens. Keeping of oxen for land preparation is predominant in Kisii, whereas in Muranga it is confined to the cotton zone.

Land Preparation

This starts before onset of rains, during January and July in Bosongo and during March and then from June to September in Muranga. Land is prepared using hoes or ox drawn ploughs: farmers in Muranga occasionally use pangas and tractors especially for French bean.

Cultivars

The most common cultivar is Rose Coco, adapted to high rainfall areas. In Bosongo, less common types are Canadian Wonder and a small-seeded Rose Coco type liked for its climbing habit but now abandoned due to its small seed. In Muranga, other bean cultivars besides Rose Coco are Canadian Wonder, Mwitemania and Red Haricot, this last variety being found in the tea zone. Preferred maize cultivars are 625 and 614. In both areas, farmers use their own seed or occasionally buy from local vendors. Generally, seed dressing before planting is not a common practice but some farmers use actellic, malathion or copper-based compounds.

In some cases, maize is treated with paraffin to control soil insects. Most farmers are unaware of certified seed.

Planting, Spacing and Seed Rate

Major planting seasons are February-March and July-October. Planting maize and bean in association is more common than maize or bean alone. Where bean is in pure stand, it is arranged in rows spaced 45-60 x 15-45 cm with 1-2 seeds/hill. In the maize:bean system, maize is usually arranged in rows, 75-105 x 30-75 cm with 1-3 seeds/hill.

Bean in association with maize occurs in the following arrangements:

- one row bean between maize rows, 1 seed/hill;
- bean and maize same row but different hills; and
- bean random among maize, 2-3 seeds/hill giving plant populations of 140 thousand/ha bean and 60 thousand/ha maize.

It is only in Kisii that bean and maize are planted in the same row and same hill, at a spacing of 75 x 30 cm, with one seed each of maize and bean per hill.

Usually planting is when the ground is dry. Maize is planted first then bean, after the former emerges or soon after rain starts.

Fertilizer Application

Commercial fertilizers and manures are used mainly in cash crops. The most common fertilizer is diammonium phosphate (DAP). In Bosongo, one teaspoonful DAP/hole or none may be used for bean. Boma manure may be broadcast. In Muranga, besides DAP, 20:20:0 and farmyard manure are used for maize, which may be top dressed with calcium ammonium nitrate. Bean receives only the leftover DAP. Fertilizer is obtained from local markets.

Weed Control

Weed control practices depend on the level of land preparation. One to three weedings completed by selective pulling of common weeds may be required. Weeding starts after bean germination or at the first trifoliolate leaf stage, using hoes. The use of pangas is also common in Muranga. Herbicides are not used in food crops, but they are used in cash crops, for example Gramoxone is used in coffee. It is interesting that weeds are cut and fed to livestock, especially in the coffee zone. The common weeds are annual grasses and broad-leafed species including, *Bidens pilosa* and *Galinsoga*, *Oxalis* and *Commelina* spp.

Diseases and Insect Pests

Important diseases in Kisii are halo blight, anthracnose and bean common mosaic virus. Beanflies were the most important field pests followed by aphids, systate weevil and cutworms. In Muranga, root rots were common in all zones, followed by seedborne diseases. Maize suffered attacks by stalk borer, rodents, birds and maize streak virus, which was the most serious problem in Muranga. Attempts to control pests were limited to French bean in the cotton zone using Ambush, Rogor, copper and malathion. Bean bruchids are the most important storage pests in all areas.

Harvesting, Storage and Disposal

Beans are usually harvested dry but yields are difficult to estimate. In Bosongo, 4 bags/acre of beans and 12.5-15 bags/acre of maize were recorded. Bean yields were variable in Muranga, averaging 5.5 bags/acre in the coffee zone and less than 1 bag/acre in the tea zone.

Once harvested, beans are kept in gunny bags and stored in a wooden structure with *mabati* roof or in the house. Maize is stored in a similar manner. Often the structure is cleaned thoroughly before use. Beans intended for storage are usually dressed against bean bruchid, although some farmers do not dress them. Chemicals used are actellic or malathion, depending on end use. Some farmers use a copper compound (Blue Shield) and even ash, as in the tea zone in Muranga.

Bean has various uses: it may be eaten as dry seed, fresh green seed or leaves. The stover is fed to livestock or used as mulch. In Bosongo, 75% of beans and 60% of maize are sold mainly to local vendors at Ksh. 5-12/kg. The demand for bean as food is high in Muranga where, in many cases farmers do not sell beans and maize and instead they buy them as is the case in the tea zone. Any surpluses may be sold locally at Ksh. 6-12/kg, Canadian Wonder and Rose Coco being the dry beans with the greatest market value.

Socio-economics

In all areas surveyed, the family forms an important source of labour. The wife and children do most of the work in the farm: men assist occasionally especially in the production of cash crops. Because family labour is often not readily available, most farmers hire labour, which is more expensive in Bosongo (Ksh. 55/6 man hours) than Muranga. In Muranga, labour charges range from Ksh. 20 to 35/6 man hours, usually with lunch.

Land preparation and weeding are the critical labour periods, particularly in the coffee and tea zones.

Both areas surveyed are served by the Kenya Grain Growers Cooperative Union (KGGCU) besides Kisii and Muranga Farmers Cooperative Unions. These unions provide agricultural inputs. A visit to KGGCU in Kisii town indicated that less than 100 kg of certified seed is sold in the district each year. This reflects the habit of farmers to use locally produced seed for planting.

Consumer Preferences

Rose Coco is the most preferred bean, mainly because it cooks fast and gives good gravy. Of the other beans, Canadian Wonder, which commands the highest market price, is liked for its colour and good taste but is not preferred where it has a competitive effect over maize and takes long to grow. Mwitemania is grown primarily for consumption as fresh, green, shelled beans and leaves: the dry bean, although good when mixed with other foods, is relatively slow to cook and poor in digestibility.

Production Constraints

Diseases and Insect Pests

Beanflies are the major pests affecting beans in all production zones. The major diseases are the seedborne ones and root rots.

Labour Shortage

Labour shortage was apparent due to demand by other enterprises. In most cases it was critical at land preparation and weeding.

Poor Soil Fertility

Soils were infertile due to continuous land use and failure to supply nutrients.

Poor Adoption of Recommendations.

Most farmers were unaware of certified seed and spacing recommendations or the demands imposed by other enterprises could not allow them to follow the recommendations. Consequently they use their own seed in various plant arrangements resulting in inadequate plant stands.

Drought

In the cotton zone and parts of the coffee zone drought resulted from unreliability of short rains.

Other Factors

Another factor of importance was the low market price of beans.

Research Needs

In both Kisii and Muranga, the level of adoption of new technology was generally low with regard to use of fertilizers, certified seed and correct plant populations. There is need to educate farmers to popularize new technology through on-farm demonstrations and to review agronomic practices such as plant arrangement for compatibility with farmers needs.

Diseases and pests were important problems in the areas surveyed. There is a need for on-farm loss trials to assess the importance of beanflies and seed- and soilborne diseases. There is need for research into the control of these factors.

The bean genetic diversity in both Kisii and Muranga was unimpressive. There is need for research into high yielding, disease and pest resistant cultivars adapted to farmers' agro-ecological circumstances and consumer preferences. In the meantime it would be useful to conduct on-farm work to evaluate the improved cultivars.

French bean was observed in parts of Muranga, so there is need to know more about its production.

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Exploratory Survey of the Effects of Bean Cropping Systems on Weed Composition and Predominant Weed Species

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Abstract

In view of the dynamic nature of weed populations, it is of particular significance to observe and recognize the shifts that may accompany changes in cultural practices. This is the main objective of the survey, which involved the collection and analysis of data and information from on-station and on-farm cropping systems including bean on levels of weed infestation, predominant weed species and farmers' control practices. The six most widely distributed weed species were investigated over eight locations: infestations of these weed species were found greater on-station than on-farm. Particular bean genotypes appeared to reduce the incidence of certain weed species but the differences were not significant. Infestations of couch grass were less in bean:banana associations than in pure stands of bean but infestations of other weeds were unaffected. In all areas, weed infestations were greater in early stages of crop growth, when the rains were particularly heavy.

Introduction

It is generally agreed that weeds, if allowed to get out of hand, can be a serious limiting factor to crop productivity. Conservative estimates of average crop losses due to weeds have been made in general with regard to classes of crop production. These are: 5% for class A - the most highly productive and intensive crop production situation, in which weed control is highly efficient; 10% for class B - the intermediate category of crop production, in which yields and standards of weeding are somewhat lower; and over 20% for class C - which embraces the least developed cropping systems and production methods (Parker and Fryer, 1975).

This study focuses specifically on the third situation, where very little so far has been achieved in attempting to solve weed problems. The majority of smallholdings in Uganda and, indeed in many African countries, fall under this category and account for most of the bean produced in Africa, grown in complex associations involving other crops, notably maize, banana and cassava (Allen, 1986).

Obviously, such diverse crop associations, present severe problems for herbicide use. According to Young *et al.* (1978), herbicides may provide a welcome boost to agricultural productivity under certain production situations while in others, they may impose social costs well in excess of any gains. What emerges from this dilemma is that the selection of an efficient and socially acceptable weed control system requires a thorough understanding of the agronomic, physical, economic, social and other realities of the regions of concern. This was the ultimate objective of our research.

According to Altieri and Liebman (1986), in contrast to chemical and mechanical means of weed control, the biological factors that promote crop dominance over weeds in mixed cropping systems are complex and inadequately studied. Nevertheless, these factors are small farmers' first line of defence in reducing and countering crop losses due to weed interference and are of critical importance in the design of effective weed management strategies based on multiple cropping.

Hart (1974) reported that weeds accounted for 20, 25 and 83% of the total biomass of maize, cassava and bean in pure stands, but only 16% when these crops were grown in association, implying that combinations of crops captured a greater share of available resources, thereby preempting their use by weeds (Francis, 1986).

Smother and live mulch intercrops are high-density, additive crop combinations that offer economically viable and ecologically stable means of weed control in smallhold situations. For instance, Akobundu (1989a) reported that the melon (*Citrullus lunatus*) and sweet potato could replace three hand weedings when intersown with sole yam or yam in association with maize and cassava. In this case the smother intercrop served as an appropriate, labour-saving means of weed control, at the same time enhancing erosion control through reduced tillage. The legume species, *Desmodium heterophyllum* and *Phaseolus vulgaris*, sown between rows of cassava, gave similar weed control to that achieved with continuous manual weeding (CIAT, 1980).

Akobundu (1989b) concluded that intersown legume species, serving as smother crops, contribute nitrogen to associated cereals and that this production system offers the opportunity for improving soil fertility, crop yields and weed control on otherwise improverished soils of the humid tropics.

Methodology

In the exploratory surveys, particular attention was paid to the process of problem diagnosis, which involved the assessment of the farmer's production environment and resource limitations with respect to weed control, labour and other resources. This was continuously supplemented by literature reviews as well as discussions with extensionists in their respective areas.

Farmers involved in OFTs with the national programme in Luwero, Mpigi, Tororo and Kabale were interviewed informally, without a questionnaire, but guided by a check list of important questions (Wortmann, 1989), centred on what kind of intercropping they normally practice with bean, weeding practices, bean cultivar preferences and the effect of their growth characteristics on weed populations. This type of survey - based on observations of farm activities and cropping practices as well as discussions with farmers - was used because it is relatively fast and can provide vital information which, though not in statistical form, can nevertheless be crucial in the process of problem diagnosis and identification and the subsequent planning of trials (Stroud, 1989).

On the other hand, while it is true that more intensive cropping will reduce weed problems to a certain extent due to more vigorous crop vegetation and shading, it is equally true that each cropping system will have its own weed problems, the main aspect being the nature of the weed species present

(Plucknett *et al.*, 1976). In this regard, collection of data on levels of weed infestation and predominant weed species on-station and on-farm was carried out in the first rains of 1989, while most farmer interviews were carried out during the second rains of that year. Weeds were counted using a quadrat, while dry weights were rated in bean yield trials on-station at Kawanda, Kachwekano, Kamenyamiggo, Bulindi, Rubare and Bukalasa.

The relative occurrence of six main weed species, *Digitaria scalarum, Oxalis latifolia, Bidens pilosa, Commelina benghalensis, Galinsoga parviflora* and *Cyperus rotundus* was investigated.

Results and Discussion

These six weed species accounted for 75.8% of all weed flora on-station (Table 1) and 56.2% on-farm (Table 2). This suggests that the competitiveness of these species is enhanced more by cropping practices prevailing on-station than by those practised on-farm. Infestations of *D. scalarum* and *C. benghalensis*, were greatest on-station and *C. rotundus* and *G. parviflora* were more on-farm. Differences among weed dry weights were not significant, perhaps because they were recorded only to 10 g.

On-station at Kawanda, *D. scalarum* was more serious in bean in pure stand than in association with banana but cropping system did not significantly affect infestations by other weed species.

In all areas covered, weeds posed the biggest problem in the early stages of growth of bean, when the rains were particularly heavy. Eighty per cent of farmers normally grew bean in association with one or two other crops for two main reasons: to obtain a heavier biological yield per unit area; and, to reduce space that would otherwise be occupied by weeds, in that order. Of the 25 farmers interviewed, only one had ever used herbicides. Most farmsteads were less than 0.5 ha area (93%) and only family labour was used for weeding and other operations during the season.

Table 1. Infestation Levels On-station (no./m^2) of Selected Weed Species at 6 Weeks After Sowing.

Weed species	Bul-undi	Kaw-anda	Kach-wekano	Kamen-yamiggo	Rub-are	Buk-alasa	Mean
D. scalarum	0.7	17.9	32.6	17.2	1.3	2.3	1[illegible].0
O. latifolia	14.2	15.3	0	0	0	4.2	1.8
B. pilosa	0	1.1	3.6	0	3.6	0	1.4
C. benghalensis	0	1.4	7.9	0.5	2.1	8.5	3.4
G. parviflora	0	4.0	2.3	0	3.2	6.9	2.7
C. rotundus	0	0	1.1	0	1.5	1.8	0.7
Total (%)	63.4	93.6	87.5	85.0	66.8	88.8	75.8

Table 2. Infestation Levels On-farm (no./m^2) of Selected Weed Species at 6 Weeks After Sowing (nine OFTs).

Weed species	Luwero	Mpigi	Mean
D. scalarum	0.0	2.5	1.3
O. latifolia	0.0	3.4	1.7
B. pilosa	5.7	4.3	5.0
C. benghalensis	1.3	6.6	4.0
G. parviflora	4.5	8.2	6.4
C. rotundus	8.9	5.1	7.0
Total (%)	45.4	66.9	56.2

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Bean Yield Loss Assessment Trials in Uganda

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Abstract

Diagnostic surveys were conducted in Luwero, Mpigi, Rakai and Kabale Districts to identify the farmers' major problems in bean production. Soil infertility, beanfly damage, use of unimproved cultivars and disease were among the priority problems. To determine the importance of the various production constraints, exploratory trials were conducted on farmers' fields during the two wet seasons of 1988. An incomplete factorial (plus one) design was used to investigate the effects of fertilizer (nitrogen and phosphorus) application, beanfly control, the use of the recommended variety (K20) and the control of fungal diseases, on bean seed yield. The fertilizer was applied at the rate of 33 kg N plus 25 kg P_2O_5/ha. Endosulfan was used to control beanflies. Partial control of fungal diseases was achieved by seed dressing with Thiram and Benlate. The variety K20 was compared with farmers' cultivars to determine varietal effects. The greatest yield loss, over 50%, was due to either nitrogen or phosphorus deficiency or a combination of the two. Seed dressing with insecticide and fungicide resulted in increased yields but the differences were not statistically significant. Generally, K20 was not superior to farmers' cultivars.

Introduction

In Uganda, bean production has been on the decrease for the past 25 years. The key factors to this decline in bean production are unavailability of improved seed and lack of improved production technology. The recommended bean cultivar, K20, was released in 1968 but the original seed was never replenished as there was no periodic provision of breeders' seed. Consequently, K20 is now considered susceptible to diseases like rust (*Uromyces appendiculatus*) and angular leaf spot (*Phaeoisariopsis griseola*).

Angular leaf spot is an important disease in many bean production areas of the World, especially in places where warm temperatures are common during the growing season (Hagedorn and Rand, 1986). It is one of the major diseases of bean in Uganda, where it is widespread throughout the country. Yield losses of 40 to 80 percent due to angular leaf spot have been reported in Colombia (Posada, 1981). Seeds, crop debris, off-season crops and volunteer plants are all possible sources of angular leaf spot infection under Ugandan farm conditions (Sengooba and Mukiibi, 1986).

Bean rust is among the common diseases of bean in Uganda, though its effect on yield is not well documented. In the United States, Posada (1981) reported yield losses of up to 80 percent due to bean rust infection.

In addition to diseases, pests contribute to yield reduction in bean. The beanfly, *Ophiomyia phaseoli* Tryon, is one of the major pests of bean in

Uganda. In Tanzania, Karel and Matee (1986) reported seed yield losses of 33 percent due to damage by beanflies.

Most cultivars grown by farmers, such as Kanyebwa, Kayinja, and Nambaale, are highly susceptible to pests and diseases. The majority of Ugandan farmers do not use insecticides, fungicides, and fertilizers on bean. This is because they feel that the additional benefit obtained from the improved yield would not offset the cost of the inputs used. Thus, most of the arable land is continuously cultivated without replacement of nutrients. The use of green manure is not common, though a few farmers use farmyard manure.

As farmers generally have no effective control of pests and diseases and do not improve soil fertility, it is important to determine which factors contribute most to yield loss in bean. These trials were therefore conducted with the objective of determining the relative importance of the various production constraints: fungal diseases, beanflies, bean cultivar and soil fertility.

Materials and Methods

The trials were conducted during the first and second rains of 1988, in the districts of Luwero, Mpigi, Rakai and Kabale on five farms per district, with two replications per farm. The design used was an incomplete factorial (plus one). The treatments included: seed dressing with 0.2 g endosulfan/kg of seed for beanfly control; seed dressing with a combination of Thiram and Benlate at 0.3 g fungicide/kg seed for disease control; seed dressing with endosulfan, Thiram and Benlate; use of K20; 33 kg N/ha applied as calcium ammonium nitrate (CAN) plus 25 kg P_2O_5/ha; farmers' cultivars with no other inputs (Farmers' Practice). Management practices, other than those specified as treatments were the same for all treatments, and were farmers' normal practices. The plot size was 3 x 4 m.

Beanflies (number of pupae per five plants), seedling damping off, diseases (scale of 0-9), vigour, pod load, grain yields and stands were recorded.

Results and Discussion

Luwero

Grain yields were generally low in Luwero, ranging from 80 to 504 kg/ha, but fertilizer application more than doubled yield during the first season of 1988 and produced significant ($P<0.05$) yield increases in both seasons (Tables 1 and 2).

Thiram and Benlate reduced angular leaf spot and rust, but the use of fungicides alone did not significantly increase yield. Thus, angular leaf spot and rust were not among the important factors reducing bean yields in Luwero during 1988.

Endosulfan significantly reduced the numbers of beanfly pupae and there was a resultant increase in yield during the first season.

Table 1. Effect of Fungicide, Endosulfan, Cultivar and Fertilizer on Bean Grain Yield in the First Season of 1988.

Treatment	Beanfly count	Angular leaf spot	Rust	Yield kg/ha
Luwero District				
Fungicide	2.2	4.7	2.2	80
Endosulfan	1.0	5.8	2.8	147
Fungicide + Endosulfan	1.3	5.2	2.8	144
K20	2.5	6.5	3.7	84
Fertilizer	2.8	6.5	3.0	191
Farmers' Practice	3.2	6.8	3.5	80
L.S.D. (P = 0.05)	1.66	0.62	0.69	51.7
Mpigi District				
Fungicide	3.8	NR	NR	1240
Endosulfan	0.4	NR	NR	1210
Fungicide + Endosulfan	0.0	NR	NR	1460
K20	4.2	NR	NR	1180
Fertilizer	3.6	NR	NR	1410
Farmers' Practice	4.8	NR	NR	1290
L.S.D. (P = 0.05)	2.56	NR	NR	316
Rakai District				
Fungicide	3.3	3.5	5.3	669
Endosulfan	0.1	4.5	6.5	482
Fungicide + Endosulfan	0.5	3.8	5.3	594
K20	1.8	5.6	6.6	682
Fertilizer	3.1	5.1	6.8	1056
Farmers' Practice	5.5	5.5	7.0	873
L.S.D. (P = 0.05)	1.67	0.69	0.89	364

NR = not recorded

Mpigi

During the first season of 1988, where endosulfan was applied, there was much less bean seedling loss, a large reduction in numbers of beanfly pupae (Table 1) and improved seedling vigour. Damping off was reduced by fungicide treatments but other diseases were not affected. Yield was unaffected by any of the treatments.

During the second season, endosulfan again significantly reduced the numbers of beanfly pupae but did not improve yield (Table 2). The combination of fungicide and endosulfan improved yield significantly ($P<0.05$) compared with endosulfan or fungicide alone. Fertilizer application also increased yields.

Rakai

Endosulfan again reduced the numbers of beanfly pupae (Table 1), but did not increase yields. Fungicide reduced angular leaf spot and rust but other diseases were not affected. Fertilizer significantly increased yield.

Table 2. Effect of Beanfly and Fertilizer Application on Bean Grain Yield during the Second Season of 1988.

Treatment	Beanfly count	Yield kg/ha
Luwero District		
Fungicide	2.6	351
Endosulfan	0.1	317
Fungicide + Endosulfan	0.3	320
K20	3.2	298
Fertilizer	4.0	504
Farmers' Practice	3.3	296
L.S.D. (P = 0.05)	0.51	85.1
Mpigi District		
Fungicide	2.6	300
Endosulfan	1.1	325
Fungicide + Endosulfan	0.9	412
K20	3.7	392
Fertilizer	3.7	404
Farmers' Practice	3.8	314
L.S.D. (P = 0.05)	0.41	83.1
Kabale District		
Fungicide	3.8	1060
Endosulfan	1.0	1042
Fungicide + Endosulfan	0.3	1121
K20	3.9	842
Fertilizer	4.3	1575
Farmers' Practice	4.5	917
L.S.D. (P = 0.05)	0.44	307.9

Kabale

Fertilizer application gave significant ($P<0.05$) increases in yield - up to 730 kg/ha (Table 2). Kabale is one of the most densely populated districts in Uganda and hence the land owned by each farmer is quite small. The land is hilly, with steep slopes which encourage soil erosion. As the soil loses nutrients through continuous cultivation and soil erosion, yield response to fertilizer application is large.

Endosulfan and the combination of endosulfan and fungicide significantly reduced the numbers of beanfly pupae but did not significantly improve yields, presumably because the level of beanfly infestation was not sufficiently great.

In all four districts, it is probable that responses to fertilizer would have been greater with larger N and P levels and with application of other nutrients. The overall mean yield of K20 was similar to that of the farmers' cultivars. Other environmental factors (for example, rainfall, weeds and other soil nutrients) not included in the experiment may also have affected the results.

Conclusions

Among the constraints considered, failure to meet the bean crops' nutritional requirements for N and P is most important, followed by angular leaf spot and rust. Damage by beanflies appears to be of less importance. K20 generally did not perform better than the farmers' cultivars. There is a need for cultivars superior in both yield and disease resistance.

As a continuation of this study, nutritional screening trials have been conducted to determine the relative importance of nutrient deficiencies in bean production.

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Effects of Sowing Dates and Fertilizer on Grain Yields of Haricot Bean (Phaseolus vulgaris)

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Abstract

A study was conducted during the 1987 cropping season to determine the effects of times of sowing and fertilizer on the yield of two haricot bean cultivars (local and B-933) under rainfed conditions. Five sowing dates at intervals of ten days commencing 1 June and two levels of fertilizer (0 and 100 kg/ha DAP) were compared in a factorial arrangement using a split plot design with fertilizer treatments as main plots and sowing dates and cultivars as sub-plots. Plant populations, seed sizes and grain yields all decreased with delay in sowing. Plant populations and grain yields were greater and seeds smaller in B-933 than in the local cultivar. Fertilizer application did not affect any of the characters recorded.

Introduction

Haricot bean is one of the most important crops grown by farmers in Sidamo, in southern Ethiopia. It is grown in either pure stand or in association with crops like maize (Raya, 1988; Getahun and Tenaw, 1989). Farmers of Sidamo and Wolayita Districts (Sidamo Region) use bean as a source of food (protein supplement) or cash. The cultivar grown is local and has a red seed. Yields in both districts range from 500 to 800 kg/ha and are poor compared to national mean yields of 800-900 kg/ha and research mean yields of 2-3 t/ha.

Various reasons have been suggested for the poor yields, including inappropriate time of sowing, poor soil fertility and other factors (IAR, 1977; Raya, 1988; Getahun and Tenaw, 1989). Farmers in Wolayita District plant haricot bean late (July), mainly due to double cropping necessitating three to five ploughings, which contributes to the poor yields. On the other hand, low soil fertility has also contributed to low yield. The result of planting date studies for 3 years at two locations (Awassa and Arsi Negelle) indicate that June planting favours bean yields (Tenaw, 1988). This study was initiated to examine the effect of sowing date and fertilizer on grain yield of haricot bean at Areka.

Materials and Methods

Two haricot bean cultivars, local (red seed) and improved (B-933, white seeds), were compared at five dates of sowing (at intervals of ten days beginning 1 June) and two fertilizer levels (0 and 100 kg/ha DAP) under rainfed conditions on reddish brown soils at Areka (1,750 masl). The last sowing date corresponded with farmers' date of sowing as a check. Complete factorial combinations of the treatments were arranged in a split plot with two replicates and fertilizers as main plots and cultivars and sowing dates as sub-plots. Seeds were sown in rows 40 cm apart with 10 cm between seeds along the rows. Fertilizer was applied at sowing. Plant populations at harvest, seed weights and grain yields were recorded and diseases, insects and weeds observed.

Results and Discussion

Plant stands decreased significantly with delay in sowing (Table 1) probably due to shortage of soil moisture. They were greater in B-933 (improved), and less affected by delay in sowing, than in the local cultivar.

Table 1. Effects of Sowing Dates and Cultivars on Final Plant Stands/ha ($x10^3$) of Haricot Bean at Areka in 1987.

Sowing date	Cultivar: Local		Cultivar: Improved	Mean
1 June	235		242	238
11 June	228		236	232
21 June	229		235	232
1 July	207		221	214
11 July	195		232	214
S.E.±		6.5		4.6
C.V. (%)		5.9		
Mean	219		233	
S.E.±		2.9		

Seed size also decreased with delays in sowing (Table 2) presumably due to moisture shortage during grain filling for the later sowings. The seeds of the local cultivar were significantly larger than those of B-933 but their size decreased more with delay in sowing.

Grain yields from the first three sowing dates were about 2 t/ha - twice those of the July sowings (Table 3). The reduction in yield beyond the third sowing date was about 45.5 kg/day, associated with the loss in plant stand and reduced seed size of the later sowings. B-933 produced about one third more yield (1170-2310 kg/ha) than the local cultivar (760-1985 kg/ha).

There were no significant effects of fertilizer on any of the characters recorded.

B-933 was slightly susceptible to anthracnose (*Colletotrichum lindemuthianum*) and rust (*Uromyces appendiculatus*). Both cultivars suffered insect damage.

Table 2. Effects of Sowing Dates and Cultivars on Weights of 1000 Seeds (g) of Haricot Bean at Areka in 1987.

Sowing date	Cultivar		Mean
	Local	Improved	
1 June	232	168	200
11 June	211	147	179
21 June	184	164	174
1 July	156	135	146
11 July	162	137	149
S.E.±	6.4		4.5
C.V. (%)	7.5		
Mean	189	150	
S.E.±	2.8		

Table 3. Effects of Sowing Dates and Cultivar on Grain Yields (kg/ha) of Haricot Bean at Areka in 1987.

Sowing date	Cultivar		Mean
	Local	Improved	
1 June	1985	2315	2150
11 June	1690	2270	1980
21 June	1520	2510	2020
1 July	1185	1175	1180
11 July	845	1370	1108
S.E.±	169.7		120.8
C.V. (%)	20.2		
Mean	1445	1925	
S.E.±	76.4		

Conclusions and Recommendations

The experiment confirmed previous indications that yields from June sowing of haricot bean are superior to those of farmers' practice of sowing in July. It is concluded that the optimum time of sowing of haricot bean is during the first three weeks of June for Wolayita area.

Late sowing of beans must contribute to farmers' poor yields. But farmers use late maturing maize as a preceding crop forcing them to sow a succeeding crop of bean in July. A change to a shorter duration maize will therefore be needed to enable bean to be sown in June, at the optimum time, in this double cropping sequence. In addition, a minimum tillage system using herbicide may enable earlier sowing of bean by reducing the time needed for field preparation by ploughing.

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Mulching for Rainfed Farming in a Semi-Arid Zone of Laikipia District of Kenya, September 1988-July 1989

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Abstract

On-farm tests of mulching and minimum tillage at Matanya in Laikipia District in the Rift Valley Province of Kenya are described. The area is cool and dry and has recently been settled by immigrant resource-poor farmers. Mulching and minimum tillage (MMT) and traditional practice (TP) were compared on maize (Katumani Composite B) and bean (Kat. B1) in pure stand and associated in two seasons (second season 1988 and first season 1989). In the second season of 1988, rainfall was heavy and well-distributed. Bean yields were good though maize yields were poorer than adjacent plots due to poor seed quality and damage by stalk borer. In the first season 1989, extreme drought conditions prevailed and bean produced better yields than maize due to its shorter duration. Bean yields were less in association with maize than in pure stand but in neither season was there a significant effect of cultivation practice on the yields of bean or maize. The labour required for MMT was greater than for TP in 1988 due to the extra time needed for carrying mulch, but in 1989 there was no difference in labour requirement for the two cultivation methods.

Introduction

Location of Laikipia District

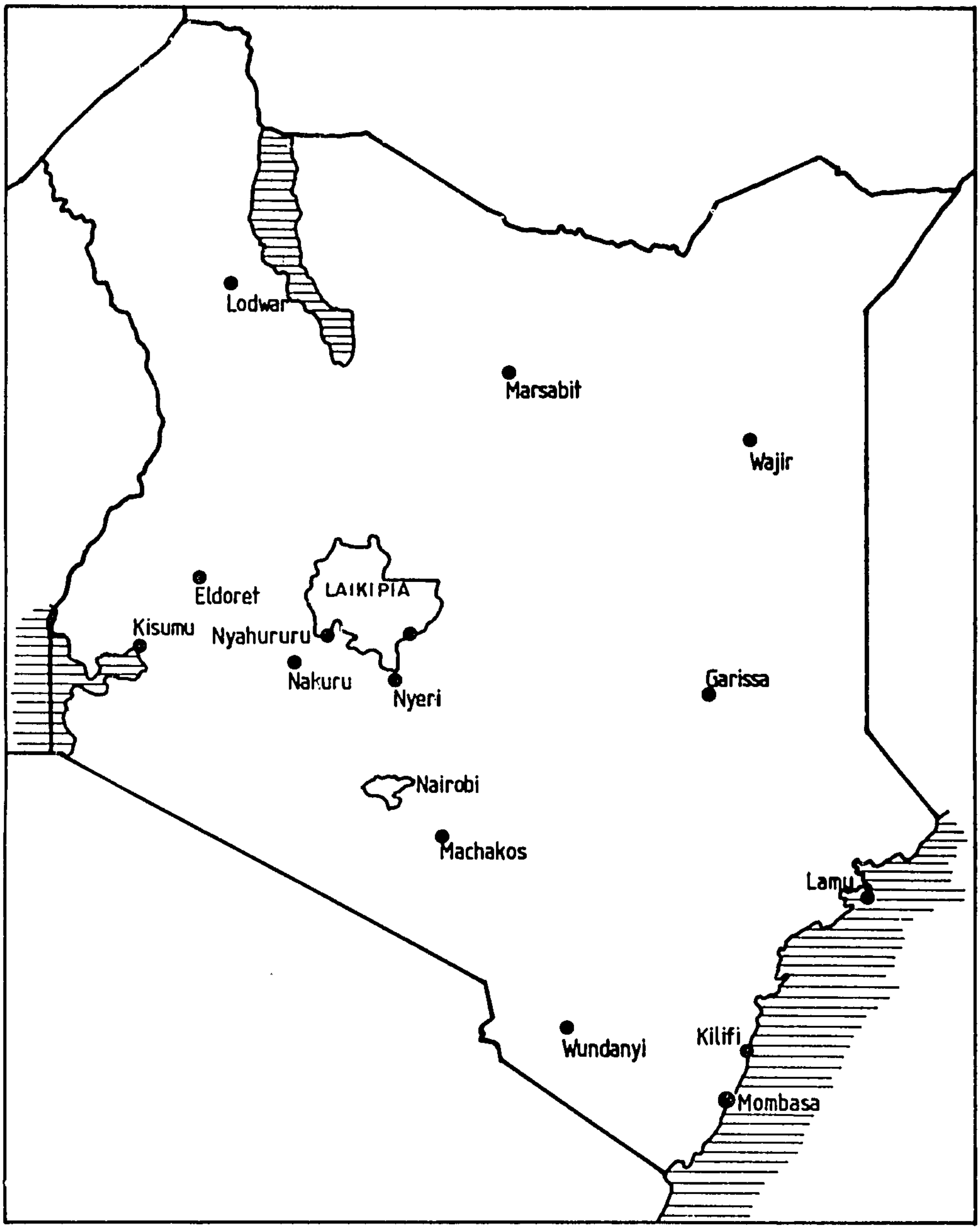
Laikipia district is in the Rift Valley Province of the Republic of Kenya (Figure 1) covering an area of 9,723 km^2. The district lies east of the Great Rift on a semi-arid high plateau 1,800-2,300 masl bounded to the south by the Aberdares and to east by the Mt. Kenya massif. Its drainage is dominated by the Ewaso Nyiro river which flows down a gentle slope from south to north.

The sources of its tributaries are Mt. Kenya and the Aberdares, which ensure a limited continuous flow throughout the year. The Laikipia Plateau receives irregularly distributed annual precipitation between 400 and 800 mm. On Mt. Kenya and the Aberdares, rainfall increases gradually up to 3,300 masl. The mean annual temperature varies from 16 to 20°C. During the year, there are small variations but daily temperatures can fall below 0°C. Annual potential evaporation is approximately 1,800-2,000 mm on the Laikipia Plateau and reduces to 1,500-1,600 mm towards the Mt. Kenya and Aberdares massifs.

Problem

There is growing awareness worldwide that natural resources are limited and are being rapidly depleted. This is not only true for treasures of the world like oil and coal but also for resources like water, arable land,

Figure 1. Location of Laikipia District.



firewood and the variety of plant and animal life. The modern agricultural methods of the "green revolution", which are based on the principles of maximizing profit and specialization in monoculture, undoubtedly brought about remarkable advances in the breeding of new cultivars which respond to good soils and proper management by producing heavy yields. These cultivars, however, require considerable capital outlays for external inputs, improved tillage and irrigation methods and high level management. The "green revolution" therefore, has had little impact on the vast majority of farmers in Laikipia, who cultivate heavy soils at subsistence levels. They could neither afford the necessary inputs, nor could the fragile ecological systems in which they practise cultivation support such technologies. In addition, the knowledge and skill to manage these modern agricultural methods have been mostly lacking. It is not realistic to expect this situation to change in the near future.

In Kenya, semi-arid lands cover about 80% of the total area and about 20% of the population depend on rainfed farming in them as an important source of income. In Laikipia, an appropriate land-use, ranching, was practised until the 1960s. However, the increased population (9%) due to immigrants from densely populated high potential areas and birth, the increasing shortage of land (1-2 ha/family), the high risk of complete crop failure because of drought and immigrants with no experience in dryland farming brings the obligation to the Kenya Government to assist these farmers who struggle for survival.

General Possible Solutions

In the long run, improved methods of semi-arid highland farming which take into account the economic constraints of farmers and still satisfy ecological principles have to be found. The new methods should increase the intensity and efficiency of production with minimal dependence on external inputs and with minimal damage to the natural resources base and the environment. They should be easily adapted for small scale farmers and combine production of food for home consumption, fodder for livestock and firewood.

For the cultivation of crops on the semi-arid lands of Laikipia, we can summarize recommendations for an improved farming method to ensure crop yields in the rain-fed conditions.

They include:

1. keeping the soil covered;

2. use of minimum tillage;

3. improving the organic matter content of soil;

4. use of drought and cold tolerant cultivars;

5. applying crop rotation;

6. use of optimum plant densities and planting dates;

7. integrating trees and shrubs into agricultural systems;

8. meeting nitrogen requirements of crops; and

9. not burning fields.

These recommendations have to be tested under local conditions through applied research in order to prepare an extension package which is tailored to the Laikipia Highlands.

Applied Research

How do we support and elaborate the recommendations under Laikipia conditions?

The Laikipia Rural Development Programme (LRDP) in collaboration with the Kenya Agricultural Research Institute (KARI) carried out experiments with drought and cold tolerant crops. To date, the results are promising for one bean cultivar from Katumani which is now being tested in on farm trials.

Furthermore LRDP and the Laikipia Research Programme (LRP) have established agro-forestry trials for the Laikipia farming system. The results are promising.

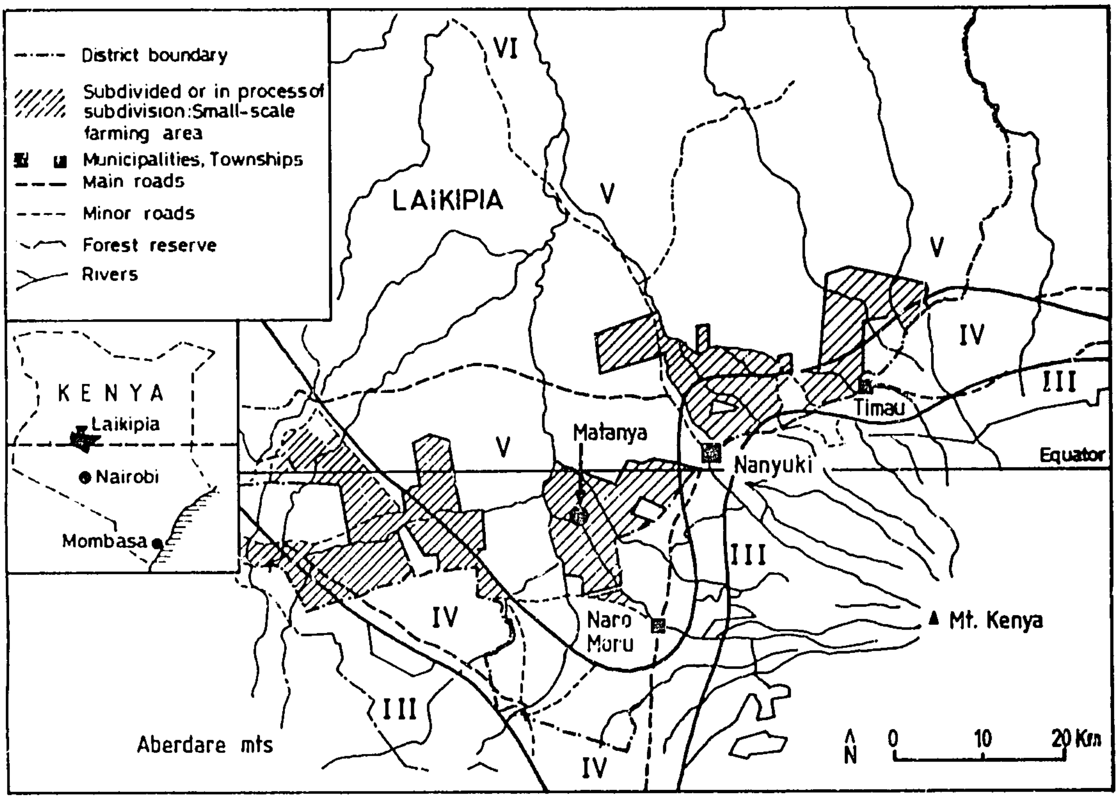
Since 1985 the LRP have carried out a study focused on water conservation methods for rainfed farming in the semi-arid highland of Laikipia (Liniger, no date). The study shows that mulching combined with minimum tillage provides very efficient water and soil water conservation, reducing evaporation loss and run-off, which increases and ensures crop yields in seasons of little rainfall and dry spells during the growing period.

Materials and Methods

The acceptance of this new cultivation practice has been assessed on farm in Matanya (Figure 2) since March 1989. On-Farm Trials (OFTs) are managed by farmers in the local farming system. In order to compare the results from OFTs with research findings and as a demonstration, the LRDP implemented a field trial in Matanya in 1989 to compare mulching and minimum tillage for water conservation with local cultivation practices.

The intercropping of maize and bean as a treatment factor is mainly chosen because it is close to the traditional practice. In reality, most farmers sow bean at the beginning of the expected rainy season. The second crop of maize in the field is sown before or after bean, at any time of the year when there is about 20 mm precipitation. With the long growing period of maize (160-200 days), sowing some rows every month staggers harvest and reduces the risk of crop failures due to drought or dry spells. We have also to consider that the Laikipia farmer by tradition always will plant maize, even after five crop failures. Choice of treatments was based on these considerations. This trial is on a practically oriented and bigger plot than on the LRP research station and provides an important feedback to researchers and demonstrates more visual and tangible results to farmers and extension staff.

Figure 2. Location Map of the Research plot in Matanya with Agro-Climatic Zones (Braun 1980): III = semi-humid, IV = semi-humid to semi-arid, V = semi-arid, VI = arid



The trials were sown in a semi-arid, lower highland area, at Tigithi, near Matanya (latitude 36°56'E, longitude 0°3'S, 1842 masl) on a clay loam soil in the second season 1988 and first season 1989. The treatments were maize (Katumani Composite B - KCB) and bean (Katumani B1 - Kat. B1) in pure stand or association with mulch and minimum tillage (MMT) or according to traditional practice (TP).

Soil preparation was by hand-hoe, 5 cm deep on the MMT plots and 15-20 cm deep for TP, on 10 September in 1988 and 14 March in 1989. The mulch, of maize residue from the previous season, was applied by hand to cover 50% of the soil, on 16 September in 1988 and 15 March in 1989. Maize and bean were sown (two seeds/hole) simultaneously on 3 October in 1988 and 22 March in 1989. For pure stands, maize was sown in rows 80 cm apart with 30 cm between holes along the row and bean in rows 40 cm apart with 20 cm between holes. In association, maize and bean were in alternate rows 40 cm apart with 40 cm between maize and 25 cm between bean positions along the rows. The treatments were in a randomized complete block design replicated four times with gross plots of 8 x 10 m, from each of which an area of 50 m^2 was harvested. Weeding was by hand with machetes and no pesticides were applied.

Data Recording

Meteorological data (mean, maximum and minimum temperatures, precipitation and per cent relative humidity at the trial site and pan A evaporation, at the LRP Station, 1 km distant) were recorded daily at 0815 and 1630 hours, Crop evapotranspiration was calculated by multiplying the crop coefficient of each growing period by pan evaporation. This is a simplified formula but gives a satisfactory approximation in Lakipia, according to the LRP.

Phenological observations were according to Rohrmoser (1985) and CIAT (1988). Times taken by casual labourers for field operations were recorded except for harvesting, because sampling was carried out. Weights of grain were recorded, adjusted to 13% moisture for maize and 9% moisture for bean. These were converted to calories and market values (1 kg of bean = 3370 calories and Kshs 5.33; and 1 kg maize = 3540 calories and Kshs. 2.67) for comparison of the cropping systems.

Results and Discussion

It is not the intention to make a detailed and complete analysis of the data. In the field, the results demonstrated the advantages and limitations of mulching to farmers and extension-staff and we gained practical experience of on-farm trials.

Weather Conditions

In the second season 1988, rainfall was heavy and well-distributed throughout the season (Table 1 and Figure 3). Relative humidities ranged between 70 and 90% and temperatures remained constant (maximum - 30°C, mean - 20°C and minimum - 10°C) (Figure 4).

Figure 3. Rainfall (mm) and Evaporation (mm) (ten day totals) at Matanya During the Growing Period 1988–89.

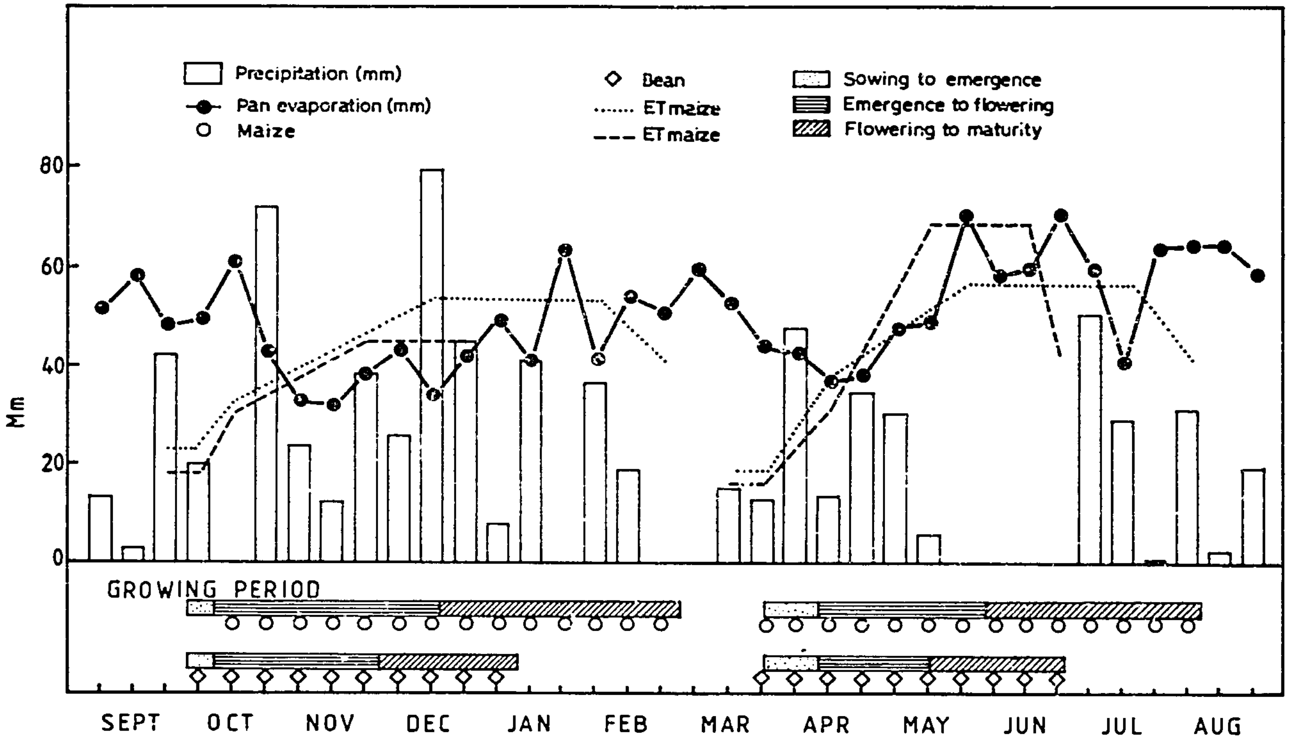
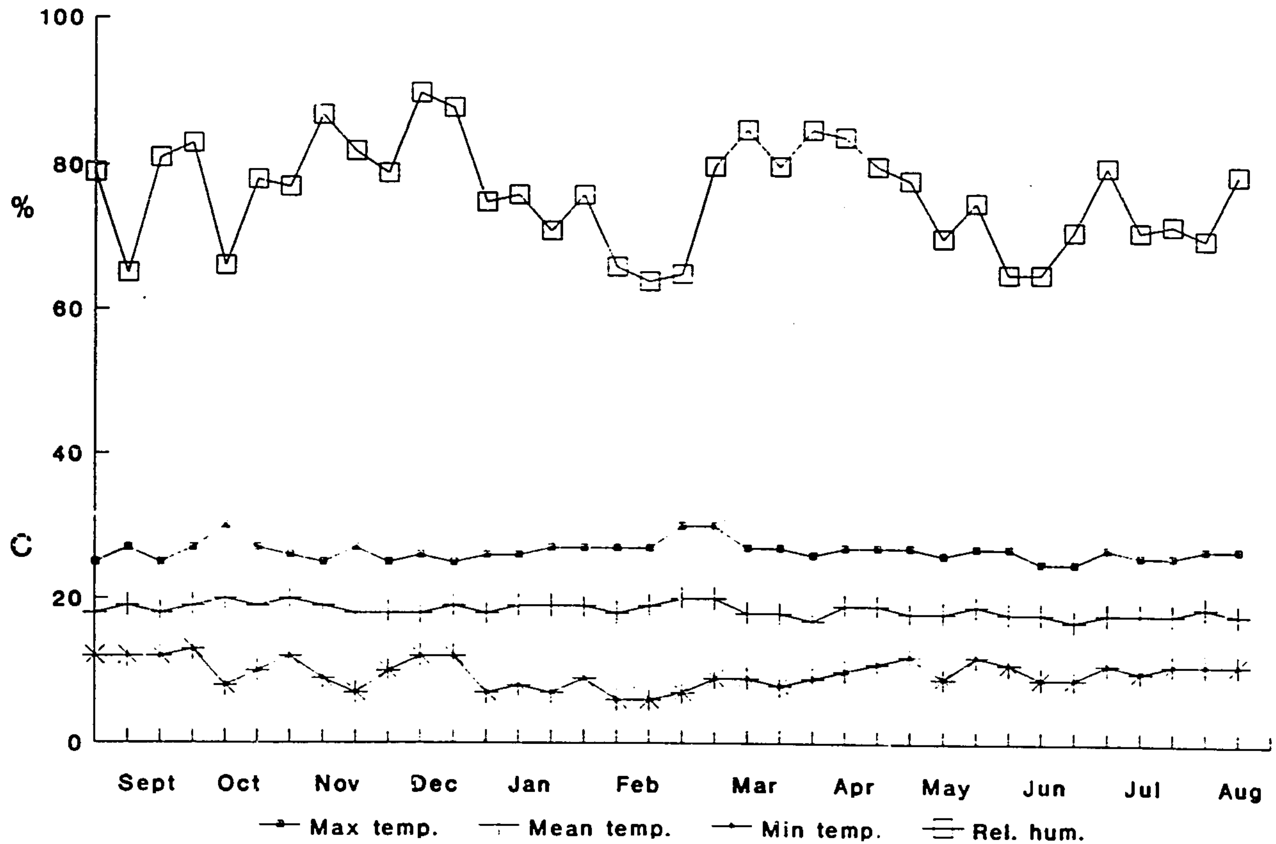


Figure 4. Temperature (oC) and relative humidity (%) at Matanya in 1988-89.



In the first season 1989, rainfall was very poor, relative humidities were between 60 and 80% and temperatures constant but a few degrees lower than the previous season.

Table 1. Precipitation and Evaporation During Different Periods of Growth of Trials at Matanya in 1988 and 1989. .rm75

	Precipitation (mm)						Pan evaporation				Crop ET
Treatment/year	HS	PS	SE	EF	FM	SM	SE	EF	FM	SM	SM
Maize MMT 1988	NA	33	17	199	202	418	16	252	350	653	538
Bean MMT 1988	NA	33	17	146	158	321	40	197	166	403	301
Maize MMT 1989	17	17	45	100	81	226	75	264	339	677	558
Bean MMT 1989	73	17	46	100	0	146	75	165	237	477	357

HS = last harvest to sowing; PS = 10 days prior to sowing;
SE = sowing to emergence; EF = emergence to flowering;
FM = flowering to maturity; SM = sowing to maturity;
ET = evapo-transpiration; NA = not applicable

Phenological Data

In the second season of 1988, cropping systems had little or no effect on phenology: maize matured just 2-4 days earlier with traditional practice than with MMT (Table 2).

In the drier conditions of the first season 1989, emergence took two to three weeks, much longer than in 1988, but was 4-5 days earlier with MMT than with TP.

Crop Performance and Yield

In 1988, bean yields were good but the yields of maize were poorer than those in adjacent trials (4 t/ha), perhaps due to poor seed quality and attack by stalk borers. Cultivation practices did not affect grain yields of either bean or maize (Table 3). This may have resulted from the unusually wet conditions reducing the advantages of MMT and the grain yields of Katumani B1, due to its susceptibility to ascochyta blight. The poor bean yields in association with maize, were also more probably limited by the wet conditions than by light competition, as the maize cultivar KCB is shorter and has smaller leaves than the locally preferred Hybrid 511.

In 1989, when extreme drought conditions were experienced, there being no precipitation from flowering to harvest, bean produced better yields than maize (Table 3) because of its shorter growing period.

Soil moisture would be greater for bean in pure stand, because the longer period between harvesting the previous crop and sowing (55 days) would store

Table 2. Phenological Data from Trials at Matanya in 1988 and 1989.

	Mulching				Traditional			
	Association		Pure stand		Association		Pure stand	
	Maize	Bean	Maize	Bean	Maize	Bean	Maize	Bean
Second season 1988 - dates								
Emergence	12 Oct	11 Oct	12 Oct	11 Oct	12 Oct	11 Oct	12 Oct	11 Oct
Flowering	14 Dec	29 Nov	14 Dec	29 Nov	14 Oct	29 Oct	14 Dec	29 Nov
Maturity	28 Feb	10 Jan	28 Feb	10 Jan	26 Feb	10 Jan	24 Dec	10 Jan
Second season 1988 - numbers of days								
HS	75	75	75	75	75	75	75	75
SE	9	8	9	8	9	8	9	8
EF	62	49	62	49	62	49	62	49
FP	54	32	54	32	52	32	50	32
PM	20	10	20	10	20	10	20	10
SM	145	99	145	99	143	99	141	99
First season of 1989 - dates								
Emergence	8 Apr	6 Apr	7 Apr	7 Apr	12 Apr	11 Apr	11 Apr	10 Apr
Flowering	2 Jun	17 May	2 Jun	17 May	2 Jun	17 May	2 Jun	17 May
Maturity	9 Aug	24 Jun	9 Aug	24 Jun	9 Aug	24 Jun	9 Aug	24 Jun
First season of 1989 - numbers of days								
HS	12	12	12	55	12	12	12	55
SE	17	15	15	16	21	20	20	19
EF	55	41	56	40	51	36	52	37
FP	49	28	49	28	49	28	49	28
PM	20	10	20	10	20	10	20	10
SM	140	94	140	94	140	94	140	94

HS = last harvest to sowing; SE = sowing to emergence;
EF = emergence to flowering; FP = flowering to podding;
PM = podding to maturity; SM = sowing to maturity

more rainfall, especially in the plots with mulch cover. This was shown by wilting of plants starting later on the mulched plots. It seemed that the mulching conserved some rain falling in April and May making water available to the plant after flowering for maybe 10-20 days. But 146 mm of rainfall from sowing to maturity is inadequate to produce reasonable yield whatever the cultivation method.

Maize grain yields were very poor and there was no benefit from mulching. There was no rainfall from two weeks before flowering to one month before maturity. On farmers' fields, all maize plants wilted and dried up before flowering. The better albeit poor yields from the trial can be explained by earlier sowing and use of the shorter duration cultivar, KCB. With the dry spell of 50 days, reasonable yields cannot be expected.

Table 3. Grain Yields (Kg, Kcals and Kshs/ha) of Maize and Bean in Trials at Matanya in 1988 and 1989.

	Grain yield (kg/ha)				Grain yields Kcal/ha			Grain yields Kshs./ha		
	MMT		TP							
Crop	Maize	Bean	Maize	Bean	MMT	TP	Mean	MMT	TP	Mean
Second season of 1988										
Maize	3128	0	2299	0	11076	14512	12795	8344	10932	9638
Bean	0	2166	0	2566	7300	8647	7974	10932	13685	12619
Maize:bean	2560	1084	2718	1028	12716	13088	12902	12609	12733	12671
S.E.±					929.9		657.6	983.0		695.1
C.V. (%)					16.6			16.9		
Mean					10365	12083		10836	12450	
S.E.±					536.9			567.5		
First season of 1989										
Maize	189	0	338	0	670	1198	934	504	903	704
Bean	0	494	0	377	1666	1272	1469	2636	2014	2326
Maize:bean	101	111	123	65	733	648	691	862	835	849
S.E.±					192.5		136.1	272.4		192.6
C.V. (%)					37.3			42.1		
Mean					1023	1040		1335	1251	
S.E.±					111.2			157.3		

The growing period of KCB maize is about 110 days in the lowlands. In Matanya, it is 140-145 days while, for Hybrid 511 it is 160-170 days. But, although the risk of complete crop failure is less with KCB, field observations show that farmers prefer the higher yield potential Hybrid 511 (5 t/ha) for relay cropping systems.

Labour Input

In the first season 1988, more man hours were needed for MMT than for the traditional practice, because the time required for mulching nowhere near compensated for the saving in land preparation and weeding time (Table 4). The time required for mulching was probably exaggerated by the need to bring mulch from outside and because it was a new practice, previously unknown to the labour.

In 1989, the total man hours for the different treatments were nearly the same. For MMT, land preparation and the mulching took even less time than traditional land preparation. Weeding took slightly longer for the mulched plots because weed growth was greater and the labourers still had insufficient experience to weeding efficiently between the mulch.

Table 4. Labour Input (Hours Per Hectare).

Activities	Dates	Mulching			Traditional		
		M:B	M	B	M:B	M	B
Second season, 1988							
Land preparation	10 Sep	250	250	250	250	250	250
Mulching	16 Sep	109	109	109	0	0	0
Sowing	3 Oct	143	73	143	143	73	143
Thinning	28 Oct	59	39	102	59	39	102
Weeding 1	27 Oct	168	141	203	180	145	174
Weeding 2	14 Nov	153	136	139	181	140	174
Harvest Bean	26 Jan	NR	0	NR	NR	0	NR
Harvest Maize	8 Mar	NR	NR	0	NR	NR	0
Total		882	748	946	813	647	843
First season 1989							
Land preparation	14 Mar	125	125	125	250	250	250
Mulching	15 Mar	70	70	100	0	0	0
Sowing	22 Mar	125	83	125	125	83	125
Thinning	2 May	61	44	71	45	55	91
Weeding 1	23 Apr	77	72	100	55	55	60
Weeding 2	4 May	90	93	95	60	68	64
Harvest Bean	12 Jul	NR	0	NR	NR	0	NR
Harvest Maize	8 Aug	NR	NR	0	NR	NR	0
Total		548	487	616	535	511	590

M = maize; B = bean; NR = not recorded

Conclusions and Recommendations

In a normal season with little precipitation and dry spells of not more than 2-3 weeks during the growing period, mulching in combination with minimum tillage is a recommended water and soil conservation method and results in increased yields, reduced risk of complete crop failure and better soil conservation which are the bases of production and life in Laikipia.

Mulching and minimum tillage require no more labour and material input than nor dramatic changes in traditional cultivation methods, thus providing a positive option for small scale farming in Laikipia.

Through the extension services, the Ministry of Agriculture and the LRDP should realize in future a great impact from the use of mulching, minimum tillage and other dryland farming recommendations in a package approach which includes what, how, when, why and limitations for a successful, sustainable land use system in Laikipia.

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The Development of a Maize-Climbing Bean Intercropping System for Central Uganda

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Abstract

Climbing bean has greater yield potential than bush bean on fertile soils, but plants need to be supported and allowed to climb to fully utilize this potential. In association with maize, support is provided by the companion crop. In parts of central Uganda, however, maize is of less importance than bean and farmers are not willing to sacrifice bean yield due to suppression by the maize. A series of experiments was conducted over three seasons at Kawanda Research Station to determine how to manage the maize-climbing bean association so that the maize supports the climbing bean with minimum suppression of bean yields. Bean yield was little affected by maize plant density, but maize yield increased with maize density. Fertilization did not improve bean yield and had little effect on total productivity. Inclusion of bush bean in the system results in increased bean yield, but reduced maize yield. Participating farmers did not like the prolonged flowering habit of G 2333 as it results in uneven pod maturity. It is concluded that G 13671 should be evaluated on farmers' fields in association with maize at densities of 2.0 and 2.5 plants per m^2, with and without bush bean.

Introduction

Climbing and semi-climbing bean cultivars (Types IIIb and IV) have greater yield potential on fertile soils than determinate, bush cultivars (Type I). To take full advantage of this yield potential and produce good quality grain, the plants need to be supported so they can climb. Research has been conducted on the association in Latin America (Davis *et al.*, 1984, Francis *et al.*, 1982a, 1982b) but, in all cases, it was assumed that farmers were willing to accept relatively poor bean yields provided maize yield was little reduced. In parts of Uganda where banana and tuber crops are important staples, bean is of greater importance than maize to farmers, who are unwilling to sacrifice bean for maize. Therefore, available research results are somewhat irrelevant for developing alternative cropping systems for these areas. The objective of this research was to determine how to manage the maize-climbing bean association so that the maize adequately supports the bean with minimum reduction in bean yields.

Materials and Methods

Experimentation began at Kawanda Research Station in the second season of 1988 and has continued for three seasons. The trials were modified each season in response to results.

Season 1988B

In 1988B, a 2^4 factorial trial with two replications was conducted. The treatments were: maize planted 10-14 days before (17 Sept) and simultaneously (30 Sept) with bean; no fertilizer and 20 kg N plus 20 kg P_2O_5 per ha at planting; maize at 2 plants 75 x 75 cm apart and 3 plants 90 x 90 cm apart; and bean plant densities of 73 and 105 thousand plants/ha.

To compare the yields of bean in association with those of bean in pure stand, the semi-climbing bean cultivar, G 13671, in pure stand was supported by stakes at final plant densities of 83 and 129 thousand plants/ha. The bean cultivar, K20, was planted at approximately 180 thousand plants/ha with maize at 22 thousand plants/ha in widely spaced stands of 3 maize plants to represent the traditional maize-bean intercropping system. Average final stand of beans, however, was only 71 thousand plants/ha.

Season 1989A

In 1989A, the trial was a 3 x 2 x 2 factorial with four replications. The treatments were: maize at 1.5, 2.0 and 2.5 plants per m^2 in single plant stands with 6, 5 and 4 climbing bean plants per maize plant, respectively; 0 and 15 kg/ha P_2O_5 at planting; and two Type IIIb bean cultivars, G 13671 and G 2333.

Plot sizes varied slightly with maize densities in all seasons but were approximately 4.25 x 5 m. Adjustments were made for the differences in plot size when estimating yield per hectare. The treatments, Type IIIb bean in pure stand and the traditional mixture, were added. Bean was planted 10 days after maize and fertilizer was applied at the time of planting bean. The bush cultivar, K20, was planted at 10 plants per m^2 between the rows of maize and climbing bean, as the climbing bean population was considered too sparse for good bean yields.

Season 1989B

Trial design and management in 1989B were similar to 1989A, except that the fertilizer treatment was replaced by presence and absence of interrow planting of Type I bean.

During this season, farmer participation in the research commenced with the invitation of several farmers to Kawanda Research Station to evaluate the various treatment combinations in the trial when the bush beans were at physiological maturity (R9) and the climbers in mid to late pod-fill (R7-R8). These farmers were informally queried about the system generally, and specifically about their impressions of labour requirements, overall productivity and of the cultivars included.

Results and Discussion

Season 1988B

Bean yields were much reduced (from 940 and 788±88.1 kg/ha, at 83 and 129 thousand plants/ha) due to competition with maize and were significantly less where maize was planted earlier rather than simultaneously with bean (Table 1). Bean yields were less with fertilizer, denser maize and denser bean, but the differences were not significant. Seeds per pod and seed size were unaffected by the treatments but, like seed yield, pods per plant were reduced by planting maize before rather than simultaneously with bean. With the traditional system, bean yields were poor (324±88.1 kg/ha), probably due to low plant density.

Maize yield per hectare was most affected by time of planting maize and slightly, by fertilization (Table 1). Maize yield components, including grain weight, cobs per plant and grains per cob, were all improved by early planting. Maize yields were larger in all the maize-climbing bean treatments than in the traditional system (1364±300.9 kg/ha). None of the interactions were significant, so their means are not reported. It was observed that bean did not climb on the maize when the two crops were planted simultaneously.

It was concluded that the combinations of management practices tested did not meet farmers' objectives and that the trial should be modified. Bean yields were much suppressed by the maize, indicating that maize populations were too dense. Also, bean should be planted later than the maize for the maize to provide adequate support. Fertilizer did not improve yields which were also little affected by bean plant density. For the following season's trial, it was decided to reduce maize plant density (from 2 to 1 plant/stand), to omit nitrogen from the fertilizer treatment and to include a second bean cultivar.

Season 1989A

In 1989A, bush bean yields were reduced by increasing maize density, but total bean yields were unaffected (Table 2). Maize yield increased linearly with maize plant density. Phosphorus application reduced bush bean yields but did not affect total bean yields. Maize yields were reduced when P was applied. Bush bean yields were greater in association with G 2333 but G 13671 gave better yields than did G 2333, so total bean and maize yields were significantly better with G 13671.

The difference between the mean total bean yield in association with maize and the yield of the traditional system was not significant and the best intercrop treatment yielded more beans, though not significantly, than the traditional system. Maize yields in association with climbing bean were 110% more than maize yields from the traditional system. The best bean yield in association was 70% of the pure stand yield of G 13671.

The yields of the bush bean between the maize-climbing bean rows were poor and contributed little to productivity. Their presence may have reduced maize and climbing bean yields, and increased the amount of labour invested in the crop, as more time was required for planting and harvesting, although weeding may have been less.

Table 1. Total Dry Matter (TDM) of Bean and Yields and Yield Components of Bean and Maize in Maize-Climbing Bean Trial at Kawanda, 1988B.

	Bean						Maize			
	TDM at R6 (g)	TDM at R9 (g)	Grain yields (kg/ha)	Weight/50 seeds (g)	Pods/ plant	Seeds/ pod	Grain yields (kg/ha)	Weight/100 seeds (g)	Cobs/ plant	Seeds/ cob
Maize before beans	3.66	7.48	262	16.11	6.95	3.95	3939	30.38	0.918	416.9
Maize with beans	6.66	11.08	362	17.43	10.08	2.52	2197	23.88	0.777	330.7
No fertilizer	4.90	8.07	323	15.75	7.07	3.84	2924	26.73	0.856	367.4
Fertilizer	5.42	10.48	302	17.79	9.36	2.64	3212	27.53	0.838	380.3
Maize 75 x 75 cm	5.54	9.89	304	16.05	8.67	2.96	3077	27.44	0.849	371.3
Maize 90 x 90 cm	4.77	8.66	321	17.50	8.36	3.51	3059	26.82	0.846	376.4
Beans 73,000/ha	6.22	9.73	334	16.34	9.00	3.52	3088	27.16	0.833	385.9
Beans 105,000/ha	4.09	8.82	291	17.20	8.04	2.95	3047	27.10	0.861	361.8
L.S.D. (P=0.05)	1.37	NC	92.5	NC	3.31	NC	277.6	0..99	0.057	94.84

NC = not calculated due to missing data

Season 1989B

In 1989B, bush bean yields were greater at the low maize density than at the higher densities, but maize density did not affect the yields of the climbers nor total yields (Table 3). Yields of the climbers were not reduced by the presence of bush beans but the total bean yield in the presence of bush bean was 22% more than the total yield without bush bean. Differences in varietal influences of the climbers on bean yields were not significant. Orthogonal partitioning of the treatments mean square for seed yield (Table 4) showed that the traditional system yielded more beans than the mean total yield of the intercropping treatments, and also more than the mean of intercropping treatments in which bush bean was included (Tables 3 and 4). The mean yields of the climbers in pure stand yielded significantly more beans than the mean of the intercropping treatments and than the traditional system.

Maize yields increased linearly with plant density, but this relationship was not significant. Maize yields were reduced by the presence of bush bean, but were much larger when intercropped with the climbers than in the traditional system. Thus, in contrast with the previous two seasons, the yields of climbing bean supported by maize were inferior to the yields of the traditional maize-bean association.

The farmers who participated in the evaluation of the system stressed the importance of even maturity of the pods to avoid multiple harvests. They did not like G 2333 for this reason. They expressed concerned about increased lodging of the maize if their local cultivars were used in the system and about the extra labour involved due to the inclusion of the bush beans.

Conclusions

It is concluded that, in the cropping systems examined at Kawanda, bean yields are little affected by maize density, within the range tested, but that

Table 2. Bean and Maize Yields in Maize-Bean Intercropping Trial at Kawanda in 1989A.

Treatment	Bush bean yield (kg/ha)	Climbing bean yield (kg/ha)	Total bean yield (kg/ha)	Maize yield (kg/ha)
Maize plant density				
2.5 plants/m^2	119	393	512	3034
2.0 plants/m^2	159	344	478	2407
1.5 plants/m^2	153	366	518	2011
L.S.D. (P = 0.05)	21.6	62.6	75.2	230.3
Phosphorus fertilizer				
No P	154	352	505	2620
P	133	383	500	2348
Bean cultivar				
G 13671	132	434	548	2525
G 2333	155	302	457	2443
L.S.D. (P = 0.05)	25.0	51.2	61.5	265.8
Best combination[a]	115	483	598	3077
Pure stand				
G 13671	NA	833	833	NA
G 2333	NA	705	705	NA
Traditional system				
K20	569	NA	569	1183
L.S.D. (P = 0.05)	69.6	147.3	137.7	624.0

NA = not applicable; [a] 2.5 maize plants ha^{-1}, P, G13671

maize yield is favoured by higher maize plant density. G 13671 gave slightly higher yields than G 2333, but both cultivars responded similarly to the other experimental variables. The participating farmers did not like the long flowering period of G 2333 as they want to avoid multiple harvests. For those that harvest fresh beans and green leaves, the prolonged flowering may be desirable for home consumption. Application of small amounts of nitrogen and phosphorus fertilizers did not improve bean yield. Inclusion of bush bean results in significantly more bean yield, but because this modification requires more labour and management, it may not result in improved profitability.

Studies of the agronomic and socio-economic aspects of the cropping system will continue on farmers' fields in 1990, in simple trials of six treatments in Luwero district. The treatments include: the planting of maize at two densities, with and without the inclusion of Type I bean; the traditional maize bean system; and the Type III cultivar in pure stand supported by stakes. The contributions of farmers to the further development

Table 3. Bean and Maize Yields in Maize-Bean Intercropping Trial at Kawanda in 1989B

Treatment	Bush bean yield (kg/ha)	Climbing bean yield (kg/ha)	Total bean yield (kg/ha)	Maize yield (kg/ha)
Maize plant density				
$2.5/m^2$	114	413	506	4544
$2.0/m^2$	107	447	545	4334
$1.5/m^2$	152	412	595	4071
L.S.D. (P=0.05)	33.7	74.8	88.0	587.7
Bush beans				
Absent	NA	445	494	4534
Present	249	404	603	4098
Bean cultivar				
G 13671	134	439	574	4273
G 2333	115	410	523	4359
L.S.D. (P=0.05)	28.7	61.1	71.8	479.8
Pure stand				
G 13671	NA	1274	1274	NA
G 2333	NA	1505	1505	NA
Traditional system				
K20	895	NA	895	2739
L.S.D. (P=0.05)			296.1	1307.2

NA = not applicable

Table 4. Some Components of the Treatments Mean Squares for Bean Seed Yields in Intercropping Trial at Kawanda in 1989B.

Source of variation	df	Mean squares
Treatments	14	392038**
Intercropping mean vs. pure stand of climbers	1	4851299**
Intercropping mean vs. traditional system	1	443334**
Pure stand of climbers vs. traditional system	1	652366**
G2333 vs. G13671 (pure)	1	106984ns
Traditional system vs. mean of intercropping with bush beans present	1	271957*
Linear effect of maize density	1	91814ns
Error	42	33146

and evaluation of the system will be documented to learn more about farmer participation in cropping system development. Adoption by farmers will be studied in Luwero district if an acceptable system is developed.

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The Productivity of Plant Sugar Cane Intercropped Simultaneously with Maize and Bean

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Abstract

In ten trials in Mauritius in 1987 and 1988, plant sugar cane uniformly spaced at 1.6 m between rows was intercropped with bean and maize, alone or together. At low density, the yield of bean increased proportionately with increasing density, but not at the high density. Maize grain yield also increased with increasing density but not proportionately. Neither bean nor maize yields were reduced in the presence of sugar cane. Maize reduced cane tillering, especially at high density. Cane and sugar yields were decreased with maize in every interrow of sugar cane, with bean at the highest density and with maize and bean together. The productivity of all the associated systems was greater than sugar cane in pure stand. The most productive system was sugar cane in association with bean at high density.

Introduction

Sugar cane is the dominant crop in Mauritius, occupying 93% of the cultivated land area. Agricultural policy dictates the pursual of diversification only while maintaining total sugar production. As sugar yield cannot be increased substantially and land is scarce, agricultural diversification can therefore only be achieved by cropping systems that intensify production and increase land productivity. The intercropping of sugar cane offers such prospects.

The intercropping of sugar cane with food crops is already practised on a commercial scale, constituting a considerable proportion of production - 55% for groundnuts (Ismael and Govinden, 1989), 80% for potato (Anon, 1980-85) and 59% for maize (Govinden and Mauree, 1986). Since 1983, national policy has promoted the development of dry bean production, necessitating further increase in the productivity of sugar cane in association with other crops.

Under the existing system of sugar cane production, maize is grown in every interrow of plant sugar cane or every two interrows, leaving alternate interrows unsown. Sowing maize in every interrow reduces cane yields; the latter practice does not (Anon., 1977), so is the most common practice, but under-utilizes land.

The introduction of bean into the interrows without maize would intensify cropping and make better use of land. Initial studies conducted in 1984 (Anon., 1985; 1987), produced contrasting results. In 1984 (but not in 1986), two rows of bean and one of maize in alternate interrows of sugar cane reduced cane and sugar yields. The aim of the present study was to evaluate the effects of various associations of bean, maize and maize:bean with sugar cane on productivity.

Materials and Methods

In 1987 and 1988, a series of ten randomized complete block trials with six replicates were established in plant sugar cane. The characteristics of the locations, the sugar cane cultivars and the dates of sowing and harvesting are listed in Table 1.

Table 1. Characteristics of locations, sugar cane cultivars and sowing and harvesting dates of sugar cane intercropping trials in Mauritius in 1987 and 1988.

	1987					1988				
Location	BO	BASF	SH	MTMD	M	BO	BASF	SH	MTMD	BRSES
Altitude (masl)	70	75	75	40	90	27	121	48	55	480
Climatic zone	H	H	H	H	SBH	H	H	H	H	SPH
Rainfall (mm)	1500	1725	1650	1600	800	1500	1950	1800	1600	3200
Soil type	LHL	LHL	LHL	LRP	LRP	LHL	LHL	LRP	LRP	HFL
Sugar cane cultivar	M 1030/71	M 1030/71	M 1030/71	M 555/60	M 126/63	M 1557/70	R 570	M 695/69	M 1557/70	M 3035/66
Dates of sowing										
Sugar cane	29 Jul	5 Aug	25 Sep	11 Aug	11 Aug	23 Aug	26 Aug	12 Aug	4 Aug	31 Aug
Maize/bean	31 Jul	7 Aug	29 Sep	14 Aug	13 Aug	24 Aug	29 Aug	16 Aug	9 Aug	2 Sep
Dates of harvest										
Sugar cane	4 Oct	NR	25 Oct	NR	3 Nov	19 Sep	27 Sep	12 Sep	6 Sep	5 Oct
Maize	24 Nov	9 Dec	22 Jan	1 Dec	10 Dec	16 Dec	28 Dec	7 Dec	9 Dec	13 Jan
Bean	30 Oct	2 Nov	21 Dec	10 Nov	3 Nov	18 Nov	6 Dec	8 Nov	4 Nov	2 Dec

BO = Bel Ombre; BASF = Bel Air-St Felix; SH = Savannah; MTMD = Mon Tresor-Mon Desert; M = Medine; BRSES = Belle Rive; H = humid; SBH = sub-humid; SPH = super-humid; LHL = low humic latosol; LRP = latosolic reddish prairie; HFL = humic ferruginous latosol; NR = not recorded

Except at Belle Rive, which was rainfed, all trials were irrigated by overhead sprinklers with about 25 mm of water every 10-15 days when rainfall was deficient. Land preparation was by disc plough, alone or in combination with a sub-soiler. The furrows for sugar cane were made mechanically 1.6 m apart. Phosphate and potash were applied in the furrows at planting at 131-554 kg/ha P_2O_5 and 142-284 kg/ha K_2O. Nitrogen was top-dressed 5-6 weeks later at 123-142 kg/ha N. Factory scum at 11-28 t/ha was applied at all locations except Medine and Belle Rive. Sugar cane was planted using three bud cuttings at the rate of 31,250 cuttings/ha.

For maize and bean, the furrows were made manually. Seeds of maize hybrid U-R14 were sown a few days after the planting of sugar cane. Pure stand maize was sown at 80 cm between and 20 cm within rows. In association with sugar cane, maize was sown between the sugar cane rows and 15 cm apart within rows. Nitrogen (104 kg/ha N), phosphate (104 kg/ha P_2O_5) and potash (160 kg/ha K_2O) were applied in the furrows at sowing and 182 kg/ha N were top-dressed four weeks after sowing.

Seeds of bean cultivar Long Tom were sown at the same time as the maize. In pure stand, the rows were spaced alternately 20 and 60 cm apart, with 15 cm between plants within the rows. In association with sugar cane, bean was sown in single rows equidistant from the rows of sugar cane or in paired rows, 40 cm apart, with 10 cm between plants within rows. Nitrogen (20 kg/ha N), phosphate (20 kg/ha P_2O_5) and potash (30 kg/ha K_2O) were applied in the furrows at sowing and 34 kg/ha N were top-dressed at four weeks after sowing. Insecticides (Tamaron, Decis or Trigard plus Cuprox) and herbicides (Linuron or Preforan) were applied at standard rates.

The treatments were: pure stand sugar cane (SC), maize or bean; SC with one or two rows of bean in every SC interrow; SC with one row of maize between every SC interrow or every two interrows; and SC with one row of bean and one row of maize alternately between every SC interrow.

The yields of cane, sugar, maize and bean were recorded. Sugar yields were estimated from total cane weights and sucrose contents. Maize grain was weighed after oven drying to constant weight and yields adjusted to 12% moisture. Bean grain yields were adjusted to 14% moisture. Sugar cane tillering was recorded monthly. Relative Yield Totals (RYTs) - the sums of the ratios of the yields of sugar, maize and bean in association to their yields in pure stand - were used to evaluate the productivity of the different cropping systems in those trials where sole crop maize and bean treatments were included.

Results

Bean Grain Yields

Bean yields were poor but were better at Bel Air-St Felix in both 1987 and 1988 (Table 2). The yields of bean in single rows were greatest in pure stand and fell proportionately in association with SC and SC plus maize. The yields of bean in paired rows in association with SC were greater than single rows in association with SC. The absence of differences in bean yields per plant indicated that bean was affected by neither sugar cane nor maize.

Table 2. Bean grain yields (t/ha) in pure stand and association with sugar cane and maize in Mauritius in 1987 and 1988.

	1987					1988				
Treatment	BO	BASF	SH	MTMD	M	BO	BASF	SH	MTMD	BRSES
SC + paired rows bean	0.71	1.46	0.87	0.89	0.67	0.47	1.69	0.98	1.35	0.31
SC + single rows bean	0.45	0.68	0.46	0.53	0.44	0.20	1.07	0.63	0.72	0.15
SC:maize:bean	0.20	0.33	0.13	0.27	0.19	0.13	0.57	0.27	0.21	0.06
Pure stand bean	NI	1.72	1.80	1.03	NI	NI	2.51	NI	1.57	NI

BO = Bel Ombre; BASF = Bel Air-St Felix; SH = Savannah;
MTMD = Mon Tresor-Mon Desert; M = Medine; BRSES = Belle Rive;
NI = not included

Maize Grain Yields

Maize grain yields were excellont in all trials (Table 3). They were greatest in pure stand and least in the SC:maize:bean association, with maize in every interrow or every two interrows intermediate. Maize yields per plant were again unaffected by cropping system, though they were consistently less when in every interrow with sugar cane.

Table 3. Maize grain yields (t/ha) in pure stand and association with sugar cane and bean in Mauritius in 1987 and 1988.

Treatment	1987					1988				
	BO	BASF	SH	MTMD	M	BO	BASF	SH	MTMD	BRSES
SC:maize:bean	1.96	1.86	2.34	2.12	2.29	1.65	1.97	1.13	2.27	1.89
SC + maize alternate	2.19	1.67	2.13	2.02	2.01	1.79	1.70	1.47	2.06	1.86
SC + maize every row	3.72	3.48	3.97	3.96	3.92	3.58	3.24	2.23	3.93	3.61
Pure stand maize	NI	5.75	3.89	4.01	6.23	NI	7.07	NI	7.66	NI

BO = Bel Ombre; BASF = Bel Air-St Felix; SH = Savannah;
MTMD = Mon Tresor-Mon Desert; M = Medine; BRSES = Belle Rive;
NI = not included

Sugar Cane Tillering

Tillering of sugar cane between 10 and 26 weeks after planting was reduced in association with maize and/or bean. The magnitude of the reduction varied with location, year, sugar cane cultivar and intercrop treatment. The reduction was greatest with maize and increased with density. The effect disappeared from 26 weeks after planting.

Cane Yield

Cane yields are not available from Bel Air-St. Felix and Mon Tresor-Mon Desert in 1987, as they were not harvested by plot. In other trials, cane yields were variable (Table 4). They were reduced by maize in every row, paired rows of bean and maize:bean in association.

Sugar Yield

Sucrose content was unaffected by treatments, so sugar yields followed the same pattern as cane yields (Table 5).

Relative Yield Total (RYT)

The RYTs for the associated treatments were greater than those of the pure stands in all cases (Table 6). The most productive system was paired rows of bean in association with SC (27 per cent better than sole SC). The SC:maize:bean association was least productive.

Table 4. Cane yields (t/ha) in pure stand and associations with maize and bean in Mauritius in 1987 and 1988.

	1987			1988				
Treatment	BO	SH	M	BO	BASF	SH	MTMD	BRSES
Pure stand SC	72.9	88.7	88.0	93.5	72.3	72.5	106.6	42.5
SC + single rows bean	61.6	86.9	84.1	75.9	74.0	82.7	106.8	52.7
SC + paired rows bean	65.1	97.3	87.7	72.6	62.4	74.4	93.4	53.5
SC:maize:bean	76.6	82.3	91.3	68.7	65.4	70.5	93.1	43.9
SC + maize alternate	75.3	91.2	87.4	91.2	68.9	72.0	110.4	42.0
SC + maize every row	71.8	89.2	83.7	75.0	62.3	66.7	97.2	32.2
S.E. (±)	5.3	5.9	5.3	6.7	4.5	6.8	6.7	3.1

BO = Bel Ombre; BASF = Bel Air-St Felix; SH = Savannah;
MTMD = Mon Tresor-Mon Desert; M = Medine; BRSES = Belle Rive

Table 5. Sugar yields (t/ha) in pure stand and association with maize and bean in Mauritius in 1987 and 1988.

	1987			1988				
Treatment	BO	SH	M	BO	BASF	SH	MTMD	BRSES
Pure stand SC	9.35	11.46	12.32	8.51	7.31	7.68	11.97	4.55
SC + single rows bean	8.01	10.93	11.20	7.05	7.28	9.10	12.30	5.57
SC + paired rows bean	8.37	12.30	11.76	6.58	6.26	8.21	10.39	5.59
SC:maize:bean	9.67	10.36	11.67	6.09	6.41	7.70	9.90	4.66
SC + maize alternate	9.51	11.17	11.51	8.81	7.13	7.80	12.31	4.43
SC + maize every row	8.78	10.98	11.06	6.88	6.35	7.18	10.84	3.50
S.E. (±)	0.70	0.72	0.70	0.57	0.45	0.73	0.80	0.33

BO = Bel Ombre; BASF = Bel Air-St Felix; SH = Savannah;
MTMD = Mon Tresor-Mon Desert; M = Medine; BRSES = Belle Rive

Table 6. Relative Total Yields of Treatments in Sugar Cane, Maize and Bean Intercropping Trials in Mauritius in 1987-88.

Treatment	RYT[a]
Pure stand SC	1.0C
SC + single rows bean	1.19
SC + paired rows bean	1.27
SC:maize:bean	1.14
SC + maize alternate	1.17
SC + maize every row	1.24
Pure stand bean	1.00
Pure stand maize	1.00

[a] means of three trials

Discussion

For any crop, whether in association or in pure stand, competition occurs for a number of factors, and this ultimately affects productivity. In Mauritius, under prevailing agricultural policies, intercropping practices should aim at maintaining sugar yields while increasing the productivity of the system as a whole. In the present trials, cropping systems were identified in which greater complementarity occurred and in which greater competition (inter- or intra-specific) reduced sugar yields.

Bean is a shorter duration crop than sugar cane or maize. It therefore had little effect on SC during crop growth. As a result bean yields were influenced more by bean density than the presence of other crops. At the higher density, greater intra-specific competition must account for the lower yield response.

Maize experienced much greater intra-specific competition than bean, the competitive effect being evident at lower maize densities, when intercropped maize was in single rows. This can be at least partly explained by plant morphology - maize being taller and leafier than bean, encounters much more interaction and increased competition. Sugar cane, which grows slowly at first, was less competitive than maize, and did not affect maize yield.

Sugar cane in pure stand or association normally produces large numbers of tillers of which only a proportion reaches maturity due to intra-specific competition. The difference in the tillering pattern of associated sugar cane was the first indication that it also suffers adversely from inter-specific competition. Even after the harvest of the maize, intercropped SC never attained the tillering level of SC in pure stand. However, differences subsequently disappeared due to the loss of excess tillers through intra-specific competition. Nutrients, water and light are the three main factors for which plants compete. As each crop was fertilized separately and there was no moisture stress, maize most probably reduced tillering by competition for light. Thus, the adverse affects of maize on the SC were greater at the higher maize density.

The yield of sugar cane is dependent on the numbers and weights of millable canes. Where yield is maintained, either both components were unaffected or one component compensated for reduction of the other. Where maize was at higher density, either one or both of the components must have been affected. The adverse effects of bean was surprising, since crops of similar architecture (for example, groundnut and potato) do not reduce sugar cane yields in Mauritius. These features should be investigated.

The increased productivity from intercropping can be achieved in two ways. Where sugar yield is not reduced, intercropping is clearly advantageous. Where sugar yields are reduced, intercropping can still be more productive if the associated crop more than compensates for the loss. This was the case in three of the associated cropping treatments. However, in Mauritius, any reduction in the yield of sugar is unacceptable, even if the cropping system is more productive overall, so increased productivity is possible only by growing maize or bean at low densities.

Conclusions

The objective of intercropping is to intensify crop production and increase the productivity of land. It has been confirmed that the recommended practice of intercropping plant sugar cane with maize in every two interrows does not reduce cane or sugar yields. However, further intensifying the system by introducing bean in alternate rows adversely affected sugar cane and is therefore unacceptable. When sugar cane is not intercropped with maize, bean alone, at the lower density can be produced without adverse effect on SC. Although greater total productivity may be achieved by introducing maize or bean at greater densities, this results in reduced yields of cane and sugar.

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Identification of Acid Tolerant Bean Genotypes and their Responses to Phosphorus and Lime: a Preliminary Report

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Abstract

Bean yields in Uganda are subject to wide fluctuations, depending largely on soil acidity levels and cultivars. Very little has been done on tolerance to soil acidity or P and lime requirements. There are large deposits of phosphate rocks (PR) in Tororo and some limestones are also available: their effectiveness in improving bean yields in different soil conditions needs to be verified. Three cultivars are currently being examined - K20, Banya and Kanyebwa. In a greenhouse test, K20 failed to grow to maturity without addition of either PR or lime. Pots treated with various levels of PR and lime showed promising growth and yields. There were significant increases in available P with application of PR. Lime alone did not markedly increase available P. Combinations of 200 kg/ha P_2O_5 and 2 t/ha lime resulted in the largest uptake of P by the first and second crops. In the field, Kanyebwa appeared to be the most tolerant of the three cultivars.

Introduction

There is a wide diversity of bean (*Phaseolus vulgaris L.*) landraces and cultivars in Uganda. Bean yields average about 400 kg/ha, but are subject to very wide fluctuations, varying from total failure to over 1000 kg/ha, depending largely on soil fertility (mainly soil acidity), cultivars, seasons and pest invasions (Mukasa, 1970).

There has been little attention to tolerance to soil acidity or P and lime requirements under Uganda conditions. Also, crop responses to lime and P in acid humid tropical soils are erratic and relatively unpredictable, thus the need to obtain data for each condition (Mokwunye et al., 1986). Foster (1970) reported that bean yields increased with liming in the most acidic Ferralsols, where pH was below five and exchangeable Ca below 5 me/100 g. Mukasa-Kiggundu (1975) reported findings which indicated that soil acidity was one of the main factors responsible for the poor performance of beans in several areas of Uganda and suggested that it could be corrected by proper applications of lime and P. There is a wide range in tolerance to soil acidity among crop species and genotypes of the same species. These differences are derived from variations in sensitivity to Al and Mn toxicity and relative requirements of P, Ca, K and Mg (Foy, 1976).

Uganda has large deposits of phosphate rock at Tororo and limestone at Hima and Tororo, but they are currently undeveloped. Thus, P fertilizers and agricultural lime will continue to be imported at great cost, placing them beyond reach for most farmers. An alternative approach to the problems of soil acidity is therefore required.

The major objectives of this research project are to identify bean genotypes that are tolerant to the various types of soil acidity in Uganda and determine how grain yields can be further improved by applications of locally available P and lime materials. It is planned in three phases as follows:

a) collection of bean genotypes for testing and characterization on representative types of acid soils;

b) screening in laboratory and glasshouse to determine the characteristics responsible for acid tolerance, limits to their tolerance and responses to P and lime; and

c) on-farm testing of genotypes tolerant of soil acidity, their recommendation to farmers, agronomists and breeders and definition of characteristics associated with acid tolerance.

Materials and Methods

One glasshouse and one field trial, in progress since June 1988, are reported.

Glasshouse Trial

The trial was conducted in pots using the cultivar K20 and an acid Kitende soil (Table 1).

Table 1. Chemical and Physical Characteristics of Kitende and Kabanyolo Soils.

Analysis	Kitende	Kabanyolo
N (%)	0.50	0.13
Organic matter (%)	2.1	2.6
P (ppm)	1.75	8.30
pH	4.8	5.1
K (me/100 g)	0.11	0.50
Ca (me/100 g)	3.6	3.7
Mg (me/100 g)	0.6	1.3
CEC (me/100 g)	5.8	7.2
Sand (%)	20.4	52.7
Clay (%)	70	35
Silt (%)	8.6	12.3
Class	Red clay loam	Sandy clay loam

The treatments were: three levels of PR (up-graded to give a concentrate containing more than 40% P_2O_5 of which more than 6.1% is water soluble), equivalent to 0, 100 and 200 kg/ha P; and four levels of agricultural lime, equivalent to 0, 0.5, 1 and 2 t/ha; arranged in a completely randomized design with three replicates.

Two crops were sown. For each crop, six bean seeds were sown in each pot and thinned to four plants after germination. The pots (each containing 4 kg soil) were maintained at field capacity from 0 to 8 (first crop) and 10 to 18 (second crop) weeks. Soils were sampled at 0, 4, 8, 10, 14 and 18 weeks and analysed for available P, pH, exchangeable cations, CEC, N and organic matter.

Plants were harvested after 8 weeks by cutting stems 0.5 cm above the soil. All the plants in each pot were harvested, oven dried, weighed and then crushed and sieved for determination of P, bases and N contents.

Field Trial

The field trial was carried out at Kabanyolo with cultivars K20, Banya and Kanyebwa, each at three levels of PR (0, 100 and 200 kg/ha P), in a randomized complete block design with three replicates. Soil chemical and physical characteristics are shown in Table 1.

At maturity, whole plants were harvested, sun-dried, threshed and the seeds winnowed clean. The seeds were later sorted, sun-dried and weighed.

Results and Discussion

Glasshouse Trial

There were highly significant responses of dry matter weights and extractable phosphate to PR and lime and interactions between PR and lime (Tables 2 and 3). In the absence of either PR or lime, the plants failed to reach maturity.

At the start of the experiment, soil available phosphorus was around 2 ppm, the critical deficient level, or less (Figure 1). The level was significantly improved by the applications of PR and lime in all samples, from 4 weeks after sowing onwards, the increase due to PR being much greater than that due to lime. In some samples, there were also significant positive interactions between PR and lime. PR at 100 kg/ha and all three levels of lime alone, increased soil available P to only a little above the minimum for Uganda soils (5 ppm). P at 200 kg/ha increased soil available P to well above the minimum level by 10 weeks after sowing, but the greatest increases arose from the application of the higher levels of PR and lime together, reaching 20 ppm soil available P by 14 to 18 weeks after sowing, when it was still increasing.

At the start of the experiment, soil pHs were quite low - all except one value (5.17) lying between 4.5 and 5 (Figure 2). They were increased significantly by the application of PR and lime, but the increase was much greater with lime than with PR. The increases in soil pH due to PR may have resulted from its beneficial effects on soil microbial activity in breaking down organic matter. None of the interactions between PR and lime were significant.

Figure 1. The effects of PR and lime on the soil available P.

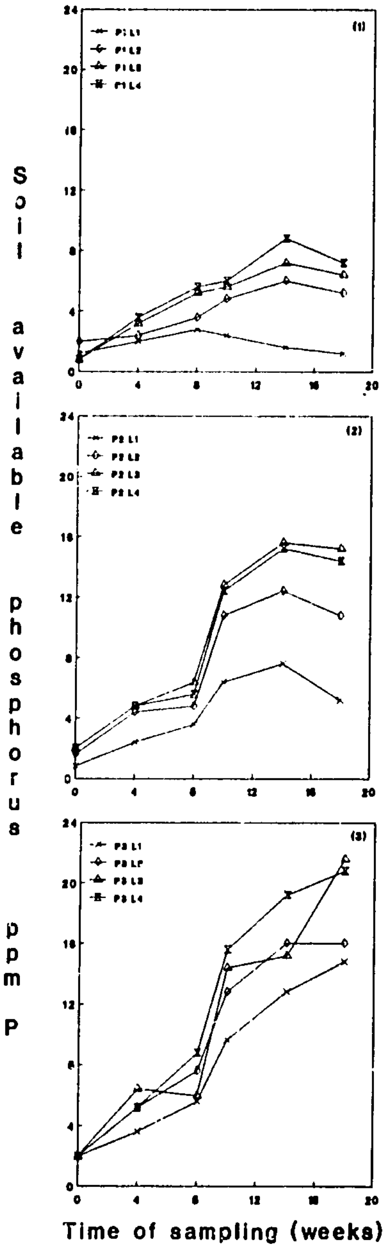

Figure 2. The effects of PR and lime on the soil pH.

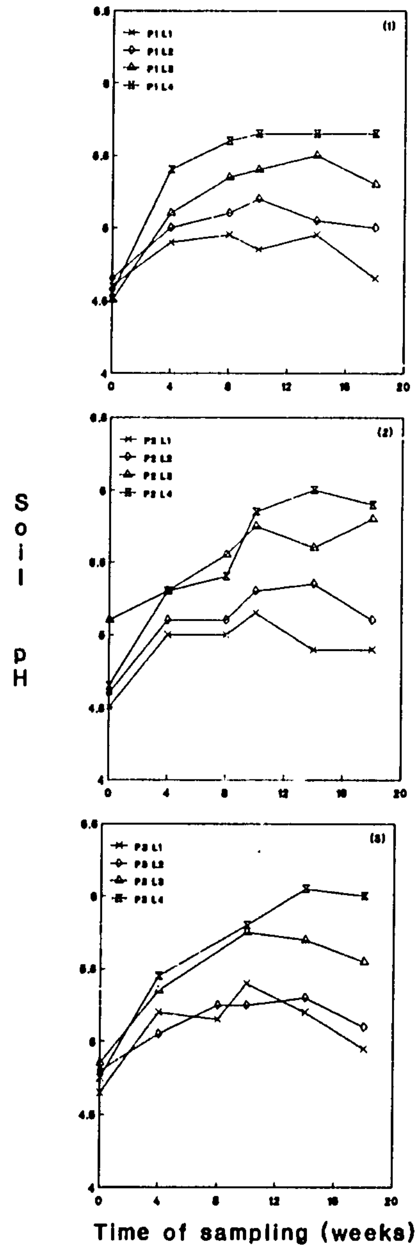

Table 2. The Effects of PR and Lime on Extractable P Content (mg/kg) of Bean in a Glasshouse at Kabanyolo in 1988.

	First crop				Second crop			
	P (kg/ha)				P (kg/ha)			
Lime (t/ha)	0	100	200	Mean	0	100	200	Mean
0	21.87	25.88	32.17	26.64	22.90	28.60	38.65	30.05
0.5	22.34	27.13	35.29	28.25	24.75	36.11	45.83	35.56
1	25.96	32.96	40.67	33.20	27.23	38.69	48.17	38.03
2	26.59	38.29	46.84	37.24	33.13	41.49	54.99	43.20
S.E.		0.962		0.555		1.149		0.664
Mean	24.19	31.07	38.74		27.00	36.22	46.91	
S.E.		0.481				0.575		
C.V. (%)		5.3				5.4		

Table 3. The Effects of PR and Lime on Dry Matter Yields of Bean in a Glasshouse at Kabanyolo in 1988.

	First crop				Second crop			
	P (kg/ha)				P (kg/ha)			
Lime (t/ha)	0	100	200	Mean	0	100	200	Mean
0	0.89	2.71	3.36	2.32	0.79	3.14	3.84	2.59
0.5	1.06	3.52	4.10	2.89	0.99	3.87	4.35	3.07
1	1.17	4.40	4.43	3.33	1.68	3.94	4.82	3.48
2	1.31	3.66	5.06	3.34	2.65	4.39	5.90	4.31
S.E.		0.256		0.148		0.144		0.083
Mean	1.11	3.57	4.23		1.52	3.83	4.72	
S.E.		0.128				0.072		
C.V. (%)		14.9				7.4		

Field Trial

In the field, there were no yield responses to PR, perhaps due to the relatively high available P (8.3 ppm) and pH (5.1) in the Kabanyolo soil. There were significant differences in yields among cultivars, suggesting that Kanyebwa (730 kg/ha) may be more tolerant of these particular soil conditions than K20 (670 kg) and Banya (525 kg/ha).

Conclusions

Although it is not possible to draw conclusions or make recommendations at this stage, these preliminary data are encouraging. The cultivar, K20 responded significantly to PR treatments without lime, the lowest applied level giving a well-marked response. In the next series of experiments, lime will be further reduced to traditional fertilizer levels.

The experiments that have been carried out on bean so far in Uganda have conceived modification of the soil environment to meet plant needs for optimum production. An alternative approach is the use of plants capable of thriving on limited supplies of the essential nutrients. Elsewhere it has been attempted to select crop plants that tolerate adverse soil conditions, usually toxic levels of soluble Al and Mn and low levels of soluble P, for example bean cultivars tolerant of high Al (Salinas, 1978). The possibility of selecting bean genotypes that are productive at low levels of available P is worth exploring.

It is hoped that more data on dry matter and seed yields, uptake of P and cations, nodulation under varying levels of soil pH and soluble P and responses to applied PR and lime, will aid screening of bean genotypes and definition of their growth characteristics under low pH and P. In collaboration with plant breeders, it should be possible to develop tolerant bean cultivars for our farmers.

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Effects of Weeding Frequency and Seed Rate on Growth and Yield of Haricot Bean Phaseolus vulgaris

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Abstract

During the 1987 and 1988 cropping seasons, experiments were conducted to determine the effect of weeding frequency and seeding rate on the growth and yield of haricot bean (Phaseolus vulgaris) in semi-arid conditions in the Rift Valley in Ethiopia. The trial was a split-split plot design with two weeding treatments (not weeded and weeded once) in main plots, three seeding rates (60, 100 and 140 kg/ha) in sub-plots and three haricot bean cultivars with different growth habits (Ex-Rico 23 - IIA, W-108 - IIB and Mexican 142 - IIIA) in sub-sub plots. High seeding rates (100-140 kg/ha) suppressed weeds and increased seed yield. With low seed rates (60 kg/ha), at least one weeding is required to increase seed yield by about 30%. Cultivars with vigorous growth habits gave reasonable yields without weeding. It can be concluded that the use of high seed rates and cultivars of vigorous growth habit can reduce the number of weedings and increase yields of haricot bean in semi-arid situations similar to the Melkassa area.

Introduction

Haricot bean is one of the major crops grown in rift valley areas of Ethiopia. It is mainly used as a cash generating crop for smallholders following teff (*Eragostis abyssinica*). Despite the importance of the crop for farmers and to the national economy for export, yield levels obtained by farmers are very poor, ranging from 600 to 800 kg/ha (Tilahun and Teshome, 1987). Weeds, moisture stress and low soil fertility are the major factors contributing to the poor yields.

The majority of bean producers (about 90%) do not weed the crop, mainly because of shortage of labor due to overlapping of farm activities. The time of weeding of bean coincides with sowing of teff and weeding of maize and sorghum (Tilahun and Teshome, 1987) and farmers give priority to the major food crops, teff and maize, in labour allocation. Moreover, herbicides are either unavailable or too expensive for resource poor farmers and their use for weed control is very limited. Improved weeding implements are not available. Thus handweeding, supplemented by traditional weeding implements is the usual practice. This is time-consuming and labour-intensive, so bean is either not weeded or weeding is performed at the wrong stage.

Consequently, weeds are major bean production problems in the rift valley. In the Melkassa area, Etagegnehu (1987) reported 37-64% grain yield reduction in bean due to weed competition. Through their long time tested experience, small farmers have developed their own strategies for controlling weeds. For instance, they use greater seed rates (100 kg/ha) to ensure better competition and suppress weed growth. Crop rotation is another strategy of controlling weeds practised by farmers. In the Melkassa area, haricot bean is grown following teff. Since teff fields are ploughed 3-4 times before planting and weeded 2-3 times, weed infestations in succeeding seasons are usually minimum.

New haricot bean cultivars with different growth habits are being tested by the Ethiopian Bean Improvement Program at Melkassa and may differ in their ability to compete with weeds. Malik *et al.* (1989) found that white bean cultivars with different architecture vary significantly in their competitive ability against weeds. The competitive ability of cultivars may be enhanced by determining the optimum seeding rates in order to suppress emerging annual weeds.

The main purpose of this study is to determine the feasibility of controlling weeds in haricot bean by use of cultivars of more vigorous growth habit and increased seeding rates.

Materials and Methods

The experiment was conducted in three different locations: at Melkassa Research Center and on farmers' fields at Wolenchite and Ziway during the 1987-1988 seasons. According to Murphy (1968), the soils are texturally sandy loams at Melkassa, clay sandy loams at Wolenchite and loams at Ziway with pHs ranging from 7.5 to 8.5. Additional descriptions of the experimental sites are in Table 1 and the major weed species are listed in Table 2.

Table 1. Description of Experimental Sites.

Location	Latitude	Longitude	Altitude (masl)	Rainfall (mm)
Melkassa	$8^{o}24'N$	$29^{o}21'E$	1550	761
Ziway	$7^{o}09'N$	$18^{o}07'E$	1650	600
Wolenchite	$8^{o}20'N$	$26^{o}21'E$	1400	550

Table 2. Major Weed Species Across Locations, 1987 and 1988.

Melkassa	Ziway	Wolenchite
Eragrostis spp.	*Eragrostis* spp	*Argemone mexicana*
Galinsoga parviflora	*Galinsoga parviflora*	*Commelina benghalensis*
Sorghum sudanensus	*Flaveria trinerva*	*Digitaria sanguinalis*
Cyperus spp.	*Tribulus terrestris*	*Leucas martinicensis*
Argemone mexicana	Other grasses	Other broad-leaved spp.

The experimental design was a split-split plot with three replications. Weeding treatments (no weeding and one weeding at third trifoliolate leaf stage) were main plots, three seeding rates (60, 100 and 140 kg/ha) were sub-plots and three bean cultivars with different growth habits (erect - Ex-Rico 23, semi-prostrate - W-108 (0177-2) and prostrate - Mexican 142) were sub-sub plots. The gross plot size was 4 x 5 m and the net area for harvesting and other records was 3 x 5 m.

The land was ploughed twice by oxen. The seeds were broadcast dry in the third week of June. Fertilizer was not applied. All other traditional management practices were at farmers' level. The times needed for weeding were recorded and weeds counted using a quadrat. Agronomic (date and per cent of seedling emergence, plant height) and phenological data were recorded at appropriate times. Seeds were harvested and weighed to determine yield per unit area and 1,000 seed weight adjusted to 10% moisture content.

Results and Discussion

Amount and distribution of rainfall were poor at all sites in 1987 but much better during 1988, when crop growth and development were better and heavier yields were obtained (Tables 3 and 4). Rainfall was less at Wolenchite than at Melkassa and Ziway in both seasons, leading to poorer yields.

For grain yields, interactions between seeding rates and weeding frequency were statistically significant at all locations during both seasons. The results from Melkassa are shown in Table 3. At the lowest seed rates, yields of haricot bean are considerably depressed without at least one weeding.

Higher seed rates suppress weed growth so that bean yields are maintained in the absence of weeding. Indeed at Melkassa in both seasons, plant damage during the weeding of plots with higher plant densities reduced yields below those of the unweeded plots.

Malik *et al.* (1989), working at Ontario on the effect of white bean cultivars, row spacings and seeding rates on establishment and suppression of annual weeds also reported that, in weedy conditions, the yields of haricot bean cultivars were significantly less in wide rows and low seeding rates than in medium and narrow rows with high seed rates.

Cultivar x seeding rate interactions were also significant for grain yields. The data from Melkassa and Ziway are shown in Tables 4 and 5). The yields of the prostrate and semi-prostrate haricot bean cultivars (Mexican 142 and W-108) were heavier and suffered less depression when not weeded than those of the erect type (Ex-Rico 23), of which yields were 25-30% less in the absence of weeding. Similar results were also reported by Malik *et al.* (1989). It was also reported that growth rates, habit and canopy structure influence the competitive ability of cultivars (Tripati and Singh, 1968; Rao and Shetty, 1977; Malik *et al.*, 1989).

Table 3. Effects of Seeding Rate on Seed Yields (kg/ha) Under Weeded and Unweeded Conditions at Melkassa in 1987 and 1988.

Weeding frequency	Seeding rate (kg/ha) 60			100			140		
	1987	1988	Mean	1987	1988	Mean	1987	1988	Mean
No weeding	960	1210	990	1000	1320	1160	1630	1533	1533
Weeding once	1620	1780	1700	1120	1270	1195	1144	1350	1247
Mean	1290	1400	1345	1060	1295	1178	2190	1490	1390

Table 4. Seed Yields (kg/ha) of Bean Cultivars of Contrasting Growth Habit Under Weeded and Unweeded Conditions at Melkassa in 1987 and 1988.

Weeding frequency	Ex-Rico 23			W-108			Mexican 142		
	1987	1988	Mean	1987	1988	Mean	1987	1988	Mean
No weeding	920	1115	1018	1122	1310	1216	1388	1420	1404
Weeding once	1020	1420	1315	1239	1390	1315	1422	1480	1451
Mean	1065	1268	1167	1181	1350	1266	1405	1450	1428

Table 5. Seed Yields (kg/ha) of Bean Cultivars of Contrasting Growth Habit Under Weeded and Unweeded Conditions at Ziway in 1987 and 1988.

Weeding frequency	Haricot bean varieties Ex-Rico 23	W-108	Mexican 142	Mean
No weeding	1124	1450	1820	1466
Weeding once	1535	1520	1933	1663
Mean	1330	1485	2787	

The main focus of this study was to develop weed control measures using agronomic management practices requiring minimum labour and low cost inout for resource poor farmers. It clearly demonstrates the importance of using haricot bean cultivars of aggressive growth habit (prostrate and semi prostrate) and high seed rates to suppress weeds and increase bean yields in rift valley areas of Ethiopia. Since these technologies require low cost and labor inputs they readily fit traditional farming systems. The information is also useful for breeders to develop cultivars which produce reasonable yields under weed competition.

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Zero Tillage in Bean Production

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Abstract

Observation trials of zero and conventional tillage revealed that zero tillage can be successfully applied to bean production. Tillage method did not influence plant height and the number of pods per plant, but affected plant stand and total seed yields. Consistent use of one herbicide Lasso (alachlor) led to build up of some weed species (<u>Tagetes</u> <u>minuta</u>). Erosion was virtually non-existent in the zero tillage plot.

Introduction

Zero tillage (ZT) describes planting crops in previously unprepared soil by opening a narrow slot, trench or band of sufficient width and depth to obtain proper seed coverage. There is no other soil preparation and herbicides are used to control weeds (Phillips and Young, 1973). Advantages associated with ZT are reduced soil erosion, better moisture conservation and reduced costs of crop production, labour and energy.

ZT has been successful with maize (Phillips and Young, 1973) and transplanted tomato (Doss *et al.*, 1981). Most research on zero tillage has been in temperate countries but little work on annual crops other than maize has been reported in the tropics. Patterson *et al.* (1986) reported lower soil temperatures with ZT than with conventional tillage (CT) and if this could be true for the tropics, then it could be an asset.

This study was conducted to evaluate the feasibility of applying ZT to bean production under tropical conditions and to confirm its reputed advantages over those of CT.

Materials and Methods

A ZT versus CT observation on bean was started in the long rains of 1986 (1986L) on the Grain Legume Project experimental field at the National Horticultural Research Center (NHRC), Thika (0^o59'S, 37^o04'E, olevation 1,550 masl) and continued during subsequent seasons until the short rains of 1989 (1989S). The site is in Agroecological Zone 3, low potential with an annual rainfall of 1,012 mm in a bimodal pattern, annual evapotranspiration of 1,214 mm and well-drained dusky reddish brown Eutric Nitosols of low to medium fertility (Anon., 1983).

The observation had two main plots: CT and ZT, lying side by side on a uniform gradient. Each main plot was 30 x 30 m net and divided into subplots A and B for rotational purposes. The area under crop for every tillage method per season was therefore, 30 x 15 m.

For CT the land was ploughed during a dry period, harrowed and planting furrows made 0.5 m apart. The fertilizer (diammonium phosphate - DAP - at 200kg ha^{-1}) was applied in the furrows and thoroughly mixed with soil before planting. The intra-row spacing was 0.1 m. Weeding was at 15-21 days after emergence and then 15-20 days later as recommended by de Groot *et al.* (1981).

The ZT plot was sprayed with the herbicide, Roundup (glyphosate) at 3-5 l ha^{-1}, when vegetation was lush. In the absence of perennial weeds, a contact non-selective herbicide such as Gramoxone (paraquat) or weed oil may be applied a few days before planting. Sowing was by dibbling seeds 0.1 m apart within rows spaced 0.5 m apart. Proper seed coverage was essential. DAP was applied in the furrows at 200 kg ha^{-1} and not incorporated. Weeds were controlled by use of Lasso (alachlor) at 3 l ha^{-1}, applied after sowing but before crop and weed emergence. Basagran (bentazon) may also be applied post emergenCE when bean plants are past the first trifoliolate leaf stage and the weeds are young enough for the control of Mexican marigold (*Tagetes minuta*), which persisted after long term use of Lasso.

Beans were harvested when all aerial parts were dry. Harvested plants were counted and a random sample of about 5 plants taken from each of 10 rows to measure plant height and count the number of filled pods. After threshing, the seed was weighed. Roots were dug and observed when the plants were actively growing and podding.

Results

Effective perennial weed control was achieved by Roundup applied at end of rains when the vegetation was lush and could absorb the systemic herbicide. Once perennial weeds were eliminated, use of cheaper contact herbicides such as Gramoxone could reduce the cost of production.

Banding DAP in the planted rows in the ZT plot was as effective as incorporating fertilizer in CT as was indicated by crop vigour four weeks after sowing. Vertical fertilizer movement into the soil was enhanced by rainFALL. It is also possible that the higher density of feeder roots just below the soil surface under ZT than under CT helped to absorb unincorporated nutrients. Plants in a row deliberately left without DAP application showed both nitrogen and phosphorus deficiency.

Maize plant leaf tissues have been shown to have just as high concentrations of phosphate (Phillips and Young, 1973) and nitrogen (Knavel and Herron, 1986) from surface application of fertilizer as from fertilizer which has been incorporated.

Lasso and Galex herbicides were effective as pre-emergent herbicides. When planting was done with weeds already emerged, Gramoxone or Roundup mixed with any of these herbicides and applied before seed emergence ensured weed control. Lasso, however, did not effectively control Mexican marigold (Muthamia, in press[a,b]). Some broadleaved weeds were not controlled by Basagran. Basagran is effective as a post-emergent herbicide, when bean is at the first trifoliolate leaf stage and weeds very young and small. Large weeds develop tolerance to the herbicide.

The benefits of the mulching effect of killed trash were not fully exploited as the trash was eaten by termites, which were particularly destructive when bean plants were mature.

Seedling emergence and growth were optimum and uniform, while poor seed coverage resulted in low seed germination due to seed rot as seed came into contact with fertilizer.

Plant vigour was similar under ZT and CT but, in the case of extended drought, plants under CT showed moisture stress symptoms earlier than those under ZT.

Under ZT, bean plants had extremely short tap roots. Lateral roots tended to spread out horizontally. This may explain the efficient utilization of immobile unincorporated phosphates. The moisture maintained by mulch dissolves the nutrients making them available to the roots close to the soil surface. Under CT, tap roots were longer while the lateral roots grew downwards.

Neither bean plant height nor number of pods per plant were influenced by tillage method. Stands were slightly more with CT than with ZT. At first, the seed yields from CT were larger than those from ZT but subsequently, with better zero tillage management skills, the yields from ZT tillage were either the same as those from CT or greater (Table 1).

Table 1. Effects of Cultivation Practices on Grain Yields (kg/ha), Plant Heights (m) and Pods/Plant of Bean Cultivars at Thika between 1986 and 1990.

Season	Character	Zero tillage		Conventional tillage
1986L	Plant height	0.298		0.276
	Pods per plant	2.9		3.4
	Grain yield	310		436
	Cultivar		GLP-2	
1986S	Plant height	0.239		0.223
	Pods per plant	4.1		4.3
	Grain yield	369		416
	Cultivar		GLP-2	
1987L	Grain yield	824		NT
	Cultivar		GLP-1004	
1987S	Grain yield	1421		1304
	Cultivar		GLP-1004	
1989S	Grain yield	1044		1011
	Cultivar		GLP-1004	

L = long rains; S = short rains; NT = not tested

Insect pest damage, especially by termites was worst with zero tillage (Muthamia, in press[b]).

The costs of bean production were too much under both tillage methods (Table 2).

Table 2. Costs of Production with Zero and Conventional Tillage between 1986 and 1989.

	Zero tillage						Conventional tillage			
Operation	1986L	1986S	1987L	1987S	1988L	1989S	1986L	1986S	1988L	1989S
Labour[a]	2142	2124	2124	1440	1332	2442	2952	3078	2276	3564
Roundup	1948	1948	1948	1948	1948	1661				
Lasso (31)[b]	390	390	390	390	390	474	1000	1000	1000	1000
Basagran (51)[c]	690						690	500	500	1000
DAP (200 kg)	1156.8	1156.8	1156.8	1156.8	1156.8	1336.8	1156.8		1156.8	1336.8
Bean seed	1140	1140	1140	1140	1140	1140	1140	1140	1140	1140
Total	7871.8	7056.8	7058.8	6374.8	6266.8	8043.8	7048.8	7174	6372.8	8340.8

[a] Kshs. 18/day, except for 1989, which is Kshs. 30/day;
[b] costs under conventional tillage are labour for ploughing;
[c] costs under conventional tillage are labour for harrowing

Discussion

Zero tillage has been successfully applied to maize production in both tropical and temperate climates. Under temperate conditions, ZT resulted in greater total dry matter and pod yield of bean than CT (Tompkins and Mullins, 1977). ZT was also reported successful on transplanted as opposed to direct-seeded tomatoes (Doss *et al.* 1981). Poor bean seed coverage resulted in decreased stand as also observed by Knavel and Herron (1986). Excessive tillage was reported to cause soil compaction and reduced yields of bean (Ghaderi *et al.*, 1981).

Fertilizer application by banding and incorporation is not necessary. Petiole tissue analysis by Knavel and Herron (1986) and Mullins *et al.* (1980) indicated that tillage does not affect leaf nitrogen and Mullins *et al.* (1980) found that phosphorus was least with CT. Patterson *et al.* (1986) reported low phosphorus in maize tissue with CT.

Annual weed control can be achieved by use of either Lasso, Galex (Anon, 1990) or Basagran. Continued use of Lasso causes build-up of Mexican marigold, so use of alternative herbicides is needed.

The mulching effect of trash was lost due to termites but erosion was virtually non existent in ZT compared to CT.

Tillage methods influenced neither plant vigour and height nor number of pods per plant. Seed yield was rather erratic, with increased yields from ZT.

Horizontal root density was greater with zero tillage but tap root development was poor.

Insect pest damage was more with ZT than with CT (Muthamia, 1989b).

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On-Farm Bean Cultivar Evaluation Trials in Uganda

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Abstract

Two bean advanced lines (A 197, BAT 1220) and seven cultivars (Carioca, G 13671, K20, Kampulike Yellow, Namunye Red, T-3 and White Haricot) were tested on-farm in the districts of Kabale, Luwero, Mpigi and Rakai. The objective was to evaluate the performance and acceptability of promising materials under farmers' conditions. Seed colour, cooking time and size, growth habit, disease reaction, taste and yield were assessed by the farmers. The bean was either sole cropped or in association with maize or banana. The treatments were replicated twice on each farm in a randomized complete block design. G 13671 was liked in Kabale, but disliked in other districts because of its lack of market, its unpopular seed colour and dislike of its trailing and indeterminate growth habit. White Haricot was accepted in Luwero, Mpigi, and Rakai districts because of its high market value, taste and short cooking time, but rejected in Kabale district because it does not keep well after cooking. K20 and Namunye Red were readily accepted in all districts because of their large seed size, red seed colour and good taste. T-3 was rejected in all districts because of its small seeds and relatively poor yield. Carioca was also rejected in all districts because of its taste and the small size and colour of its seeds. G 13671 gave significantly better yields than all other entries, followed by White Haricot. There was no difference in yield between K20 and the farmers' cultivars.

Introduction

In developing countries, where most of bean producers are subsistence farmers with limited resources, there is an increasing need for bean cultivars that are high yielding, resistant to pests and diseases and acceptable to farmers. During surveys conducted by scientists of the Uganda National Bean Program in Kabale, Luwero, Mpigi and Rakai Districts, it was found that characteristics which farmers consider in choosing a cultivar include: yield, seed colour, seed size, growth habit, taste, resistance to pests and diseases, drought tolerance and market price. Farmers are generally interested to try different bean cultivars. Sometimes cultivars that perform well on-station may not do well under farmers' conditions.

These trials were conducted with the objective of assessing the performance and acceptability of promising cultivars and breeding lines under farmers' conditions and eliciting farmers' opinions about them.

Materials and Methods

The trials were conducted during the two wet seasons of 1988 (1988A and 1988B) and the first season of 1989 (1989A), in the districts of Kabale, Luwero, Mpigi and Rakai. Ten farmers were chosen in each district and the treatments were replicated twice on each farm. The design used was a randomized complete block. The treatments included the following promising entries from on-station advanced yield trials: A 197; BAT 1220; Carioca; G 13671; K20; Kampulike Yellow; Namunye Red; T3; White Haricot; and the farmers' cultivar.

Each plot was 3 x 4 m. Farmers followed their normal management practices. The trials were planted by the farmers together with the extension agents of their districts.

Observations recorded included: insect and disease ratings; vigour; stand count; pod load; and grain yield. The following information was collected from each field: methods of land preparation and planting; previous crop; rotation; soil characteristics; inputs applied; and topography. Farmers' opinions of the entries and their preferences were elicited in meetings between participating farmers, researchers and extensionists following harvest.

Results and Discussion

The mean seed yields of the entries in trials in each district are shown in Table 1 and farmers' opinions of each entry are summarized below.

A 197

Farmers in Luwero and Mpigi liked its seed size, determinate growth habit, short maturity period and relatively high yield. But its taste and colour were not desirable and it lacked market.

BAT 1220

In Kabale, Mpigi, and Rakai, farmers disliked its small seed size. It was susceptible to the beanfly (*Ophiomyia phaseoli*), bruchids (*Acanthoscelides obtectus*) and black root. However farmers like its red seed colour and taste.

Carioca

It was rejected in Mpigi, Rakai and Kabale because of its small cream-coloured seeds and their taste. In Kabale, there was high seedling loss due to beanflies. It was also damaged by aphids (*Aphis fabae*). It was later maturing than K20 and does not shed its leaves in the field, which complicates harvesting. The pods are small in size and difficult to thresh.

G 13671

In Kabale, farmers liked the colour and size of its seeds, its vigour, tolerance to poor soils and drought and high yield. The indeterminate growth habit was liked by farmers for intercropping with maize. In Luwero, Mpigi and Rakai, it was disliked because of its seed colour and lack of market, though it gave the highest overall mean yield. It was susceptible to bean common mosaic virus.

Table 1. Mean Grain Yields (kg/ha) of Entries in On-farm Bean Variety Trials in Uganda 1988-89.

Season	Entries									
	A 197	BAT 1220	Car-ioca	G 13671	K20	Kamp-ulike Yellow	Nam-unye Red	T-3	White Har-icot	Farmers' cultivar
Kabale District										
1988A	NT	218	204	970	375	184	NT	379	197	599
1988B	345	43	NT	697	537	NT	219	558	NT	548
1989A	456	610	NT	500	692	NT	NT	NT	NT	565
Luwero District										
1988B	NT	382	326	462	380	404	266	387	475	448
1989A	1050	NT	NT	1154	955	707	NT	NT	1065	962
Mpigi District										
1988A	NT	175	204	409	175	143	214	121	200	145
1988B	239	437	NT	NT	417	419	370	NT	382	472
1989A	NT	861	NT	NT	843	718	NT	NT	1041	NT
Rakai District										
1988A	NT	202	234	467	201	164	246	140	228	166

NT = not tested

K20

In Kabale, farmers felt that the leaves were too tough to be eaten as vegetables. It was, however, liked in all four districts for its determinate growth habit, short maturity period, attractive colour, seed size and high yield. Its marketability was also emphasized. In Rakai District, farmers appreciated the loss of leaves at maturity because harvesting is simplified.

Kampulike Yellow

In Luwero, Kampulike Yellow is referred to as "Khaki". It was liked in Luwero, Rakai and Mpigi because of its good taste, short cooking time, nice seed colour, and short maturity period. Its small seed size was the only undesirable characteristic. It was unacceptable in Kabale because of its poor yield (Table 1).

Namunye Red

It was accepted in all the four districts because of the colour (red) and size of its seeds, good taste, short cooking time and high market value. It is, however, severely damaged by weevils.

T-3

In Luwero, Mpigi and Rakai, farmers liked the red seed colour but the cultivar was rejected because of its small seed, low yields and its trailing growth habit which made weeding difficult.

White Haricot

The variety was generally unacceptable in Kabale because of its small seeds, susceptibility to weevils, long maturity period, uneven ripening, poor yield and rapid deterioration after cooking. In the other three districts, high yields were obtained and farmers liked its taste, short cooking time, soft testa and high market value. In these three districts, it always commands the highest price on the market.

Farmers' Cultivars

In Kabale, most farmers grow Rushale because of its high yield, large, red-coloured seeds, short maturity period, short cooking time and for its suitability for use as green pods and leaf vegetable.

In Rakai and Mpigi, farmers grow Kanyebwa because of its good taste and high market price but its yield is very unstable. Farmers have noted that it is only suitable for newly opened land and it must be planted at a time when it will receive the correct amount of rain.

Most other farmers grow Nambale mixed with K20. They like the red mottled seed, taste, yield, short cooking time and high market value of these cultivars.

Conclusions

Generally, the most important characteristics which farmers consider when choosing a cultivar are: taste; seed size and colour; and market value. Market value appears to be determined mostly by taste. Farmers often mention yield as an important criterion, but they don't always choose the highest yielding cultivar.

Thus, farmers in Kabale accepted G 13671, Namunye Red and K20, while farmers in Luwero, Mpigi and Rakai preferred White Haricot, K20, Namunye Red and Kampulike Yellow as cultivars they would like to continue growing. The only common characteristics of these four cultivars are good taste and high market value. It appears that small, dull-coloured seeds and relatively poor yields can be tolerated, provided taste is good. When taste is not outstanding, large red-seeded varieties are preferred.

Seed for Bean Production in Sub-Saharan Africa: Issues, Problems and Possible Solutions

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Abstract

The bean seed markat for the major bean producing areas of sub-Saharan Africa is examined in this paper. Seed issues of economic importance to bean farmers are the quality and quantity of seed. Important seed quality issues are seed contaminated with pathogens that cause diseases and seed of poor physical condition. The issues of seed quantity are the availability of seed of currently used and newly released cultivars. While many diseases of bean are seedborne, the research evidence to suggest that disease infested seed is a major economic problem across wide areas in sub-Saharan Africa is sparse. Poor physical quality seed is also not expected to be an economic problem as farmers have the skills necessary to manage the planting of seed of poor condition. While these issues can be of concern to farmers in localized areas, they are not expected to be major issues in the aggregate. The market for bean seed in sub-Saharan Africa is dominated by the small scale farmer who is both a supplier and demander of seed. With few exceptions, the bean seed market is supplied by small farmers who produce grain for both consumption and marketing. Seed is supplied from within the farm or from local markets or neighbors. This market has successfully operated for a long period of time and has been shown to be remarkably resilient in times of stress. There is no evidence to show that this market has not been able to supply the many types of bean cultivars demanded by bean producers. A major seed supply problem, however, emerges when new cultivars are released. There is no marketing mechanism that can produce and distribute seed to the many potential end users. Government organized seed firms have not been able to perform these vital functions. The private sector, either on a large or small scale basis, has not entered the market because many of the preconditions for successful financial operation are not in place. A market solution to the seed supply problem for newly released cultivars may not be readily available. Non-market intervention methods may be required to achieve a sufficiently rapid diffusion of newly released cultivars.

Introduction

Common bean (*Phaseolus vulgaris*) is an important food crop for millions of small farmers throughout eastern and southern Africa. It is normally produced in traditional agricultural production systems that use few purchased inputs. Other than management and labor, seed is often the only major input allocated in these production systems. The availability of high quality seed in sufficient quantities is a necessary condition for bean to be competitive in the mix of crops produced by small farmers in these areas.

A question of major interest is whether the quality and availability of seed is a constraint to increasing both the productivity and the overall production of bean in sub-Saharan Africa. If there is a constraint of this nature, then the performance of the bean seed production and supply sector may be called into question. Importantly, a satisfactory performance in this sector is a necessary condition for farmers and consumers to benefit from bean research.

To some extent, agricultural policy makers in most sub-Saharan Africa countries have already concluded that both traditional seed producers and seed markets, especially those for cereals, can not adequately respond to the needs of farmers. As a result, publicly financed seed firms or seed units that produce and distribute seed to farmers have been established in many countries. However, the production and distribution of bean seed, as well as that of other leguminous crops, have been of secondary concern to these government sponsored seed producers, behind that of maize and other cereals.

The purpose of this paper is two-fold. The first is to identify and briefly analyze the important issues of bean seed supply and demand, including those related to newly released cultivars, for the major bean producing areas of sub-Saharan Africa. Specifically, the issues examined are seed quality and availability. The second purpose is to review strategies for intervention in the bean seed production and distribution sector in those cases in which the performance of the sector is thought to be a factor constraining production.

To put these issues into context it will be of use to briefly investigate the structure, conduct and performance of both the bean grain and bean seed production sectors. Because of the large number of agro-ecological zones and diversity in social and economic conditions in which bean production occurs in sub-Saharan Africa, it will be necessary to generalize when identifying and evaluating these sectors. Quantitative information on both the bean grain and bean seed sectors in sub-Saharan Africa is limited, requiring the extensive use of farm level interviews and observations and second hand information sources in analysis.

The remainder of this paper has five sections and a summary. In the first section, the structure, conduct and performance of the bean production industry in the major bean producing areas of sub-Saharan Africa are reviewed. The structure, conduct and performance of the bean seed industry are reviewed in the second section. The bean grain production and seed supply sectors are combined in the third section to identify the market for bean seed. In section four, bean seed quality and quantity issues are discussed. A discussion of public policy issues relevant to the bean seed market and an example of intervention in the distribution of seed follow in the final section.

Bean Grain Production in Sub-Saharan Africa

The Structure and Conduct of the Bean Grain Production Sector

Bean is widely produced in the highland areas of eastern, east-central and southern Africa and on the nearby island of Madagascar. It is a major crop in selected areas of the countries of Burundi, Kenya, Rwanda, Tanzania and Uganda and a secondary, but significant, crop in the countries of Angola, Ethiopia, Malawi, Madagascar, Mozambique and Zaire. On a national basis, Kenya is the largest producer with almost 400 thousand t produced in 1986-87 from 520 thousand ha (Gitu and Ngalyuka, 1989). In consumption, annual per capita levels are largest in the countries of Burundi and Rwanda at 58 and 37 kg, respectively (Grisley, 1990a).

Bean is typically produced on small, subsistence and semi-commercial farms under arable conditions. The absence of purchased inputs such as fertilizer, pesticides and certified seed is the production norm on these small farms. In addition to management, the most common farm or household supplied inputs are labor, seed and occasionally, manure or compost.

The predominant land tillage methods for bean production are the hoe in eastern and east-central Africa and the ox-drawn plow in Ethiopia and southern Africa. Mechanization is limited in tillage operations because of the uneconomic nature of tractor utilization, the widespread practice of the intercropping of bean with other crops and the steep terrain on which much of bean production occurs. A limited amount of mechanized production occurs on large state and co-operative farms in Ethiopia and on commercial farms in the Arusha area of Tanzania and in Zimbabwe.

Bean is frequently produced in association with the basic staple crops of maize, sorghum, banana and tubers. In these intercropped systems, bean is generally viewed as a secondary crop because of the economic importance placed on the staple food crops which are primarily targeted for subsistence. Exceptions to this rule occur in the major bean producing areas of Burundi, Rwanda and south-western Uganda, where bean is viewed as a primary crop. In southern Africa bean is frequently produced as a sole crop, but at the farm level it continues to be considered a crop of secondary importance.

The numbers of bean cultivars and land races available to farmers for planting can be considerable in selected bean producing areas. A large number of cultivars is typically planted in the countries of Burundi, Malawi, Rwanda, Tanzania, Uganda and Zaire. In these, as well as other areas, bean is produced in both pure and mixed cultivar stands. Climbing bean cultivars are widely produced in Burundi and Rwanda and in selected areas of Malawi, Tanzania, Uganda and Zaire. Bush type cultivars are preferred in most other bean producing areas of sub-Saharan Africa.

The Performance of the Bean Grain Production Sector

In the 13 countries in which bean is produced in sub-Saharan Africa, production increased at an estimated annual rate of 2.2 per cent over the 20 year period 1970-89 (Grisley, 1990a). In the aggregate, this growth in production was due entirely to area expansion as there was no significant increase in productivity. Forty-five per cent of the growth in production was due to the rapid growth in Kenya (8.9 per cent annually). Other countries with positive increases in production were Malawi, Rwanda, Tanzania and Uganda. Countries with positive growths in productivity were Kenya and Uganda, with annual productivity increases of 10 kg/ha, and Malawi, with an increase of 2 kg/ha annually.

In the most recent decade, growth in bean production in sub-Saharan Africa has slowed. The only countries found to have statistically significant increases in production were Ethiopia, Kenya, Malawi and Uganda. Malawi was the only country realizing an increase in productivity. The overall conclusion is that growth in bean production is slowing in sub-Saharan Africa and that yields are probably declining.

Bean Seed Production in Sub-Saharan Africa

The Structure and Conduct of the Bean Seed Production Sector

The structure of the bean seed industry is characterized by a large number of small producers and a few, but typically only one, large scale producers. The small seed producers are the same farmers who produce beans for home consumption and local markets. In most cases, the source of seed for these farmers is either their own grain production, neighboring farms or local markets.

In a survey of 242 households in the Central and Eastern Provinces of Kenya, Schonherr and Mbugua (1976) found that 47 per cent of farmers used their own seed, 44 per cent purchased seed from local markets, 7 per cent secured seed from neighbors and 1 per cent obtained seed from other sources. No farmer purchased certified seed from the government parastatal seed company. A similar situation can be expected across most bean producing areas in sub-Saharan Africa.

Except for a limited number of cases studied in Rwanda, there is little evidence that small farmers specialize in bean seed production in sub-Saharan Africa (CIAT, 1988). The primary reason is that the conditions necessary for the emergence of a market for specialized bean seed production by small bean farmers themselves have not developed. At the minimum, these conditions would include a widespread belief by farmers that their own seed is of low quality and that specialized producers could produce and distribute bean seed of a superior quality at a competitive price. Evidence from observation and discussions with farmers suggests that they see little economic benefit in procuring seed, usually at a higher price if available, from specialized seed sources.

Large scale seed producers in sub-Saharan Africa are typically organized as either government parastatals or as seed units within the ministries of agriculture. There are no large scale, private sector seed firms currently producing bean seed. In most cases, government controlled entities enjoy monopoly positions in national markets for improved or certified seed. The monopoly structure is often justified on the grounds that the economically optimal size seed firm is sufficiently large to warrant only a single producer for the national seed market which is usually limited in size.

The Performance of the Bean Seed Production Sector

An overwhelming share of the bean seed market in sub-Saharan Africa is believed to be dominated by small scale farmers who primarily produce beans for consumption and marketing. Given the widespread production of bean across many countries, the small farmer supplied bean seed market has performed remarkably well. There is no evidence that short-comings in this market have diminished the economic competitive position of bean in the mix of crops produced. This market has been able to accommodate for extraordinary market supply and demand conditions due to factors such as environment and civil strife when viewed over a sufficiently long period of time. Importantly, this market is self-sustaining and does not require assistance or regulation by government.

The overall performance of the large scale seed sector, which is dominated by public sector firms, is generally regarded as poor. The quantity of seed supplied has been minimal. As an example, the national seed company in Tanzania, Tanseed, supplied less than one percent of the national bean seed requirements in 1988. The performances of national seed parastatals in other countries are not expected to differ significantly.

An important difference between the small and large scale bean seed producers is the flexibility in seed types supplied. The small scale sector is able to produce seed supplies of the many different cultivars demanded by farmers. In contrast, producers in the large scale seed sector produce seeds of only a limited number of cultivars. This is an important difference in those countries in which a large number of different cultivars are commonly used. Public sector firms may be less viable in these countries.

The Bean Seed Market

In the above two sections, the structure, conduct and performance of the bean grain and bean seed production sectors were briefly reviewed. The structure of the market for bean seed can be characterized by combining information from these two sectors. This structure is shown in Figure 1 with the bean grain producers or "seed demanders" on the horizontal axis and the bean seed producers or "seed suppliers" on the vertical axis. This market is partitioned into four segments, each characterized by a different combination of seed suppliers and demanders. These market segments are identified in quadrants I, II, III, and IV of Figure 1. The direction of the supply and demand flows for seed are indicated by the arrows labelled S and D.

The market shown in quadrant I is expected to dominate the bean seed market in all sub-Saharan African countries. The bulk of bean seed is both supplied and demanded by small producers. As indicated above, in many cases the supply and demand for seed may come from the same farm. The markets shown in quadrants III and IV are typical of situations in which seed is supplied by a government parastatal or seed unit. The quantity of seed traded in these two markets is expected to be small when compared to that traded in the market shown in quadrant I.

An important characteristic of all four of the seed markets identified is that they are "demand driven". That is, the quantity of seed traded in these markets is primarily a function of demand and not supply. An increase in the quantity of seed supplied will have little effect on the quantity demanded.

This demand driven characteristic is also generally true of the large scale sector. Government seed firms produce seed and simply wait for farmers to approach them for purchases. Activities to stimulate demand are rarely engaged in by parastatals. By comparison, private sector seed firms in developed countries actively promote their products for the purpose of increasing demand. Seed markets in these countries can be characterized as "supply driven".

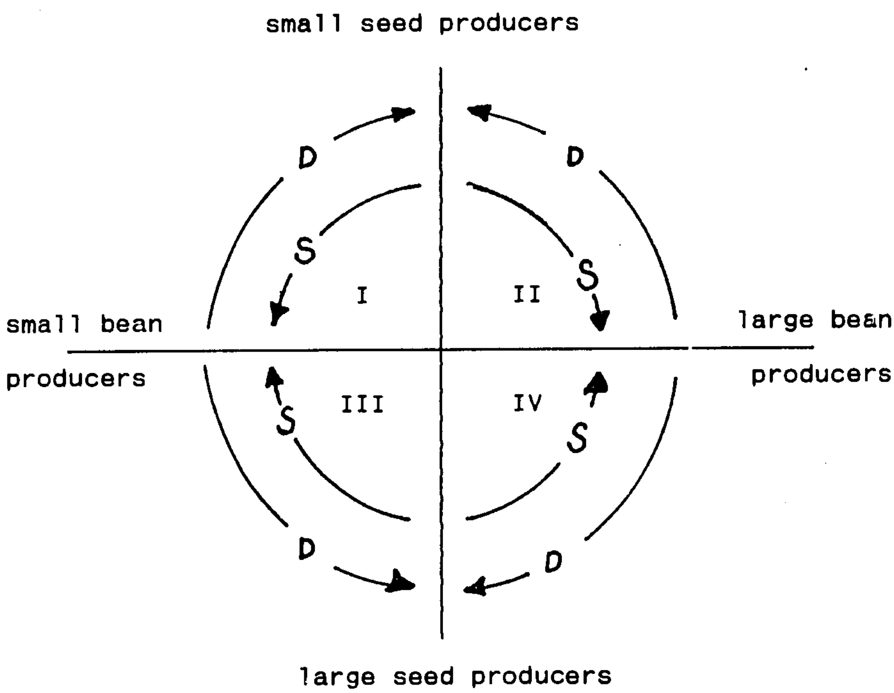

Figure 1. The structure of the bean grain and bean seed sectors in sub-Saharan Africa

Bean Seed Issues

Because seed is a necessary input in production, any factor relating to the quality and quantity of the seed can be an issue of economic relevance to farmers. In bean production, the seed quality issues of concern to farmers, aside from the genetic potential embodied in the seed, are seed free of pathogens that cause diseases and seed of good physical quality. The economic issues associated with seed quantity are the availability of seed of both currently used and newly released cultivars. These issues are discussed in more detail below.

Issues of Seed Quality

A number of viral, bacterial and fungal diseases that affect bean plants can be readily transmitted through seed. The most important are bean common mosaic virus, common bacterial blight, halo blight, brown spot, bacterial wilt, anthracnose, angular leaf spot and ascochyta blight. All but bacterial wilt are common in farmers' fields throughout bean producing areas of sub-Saharan Africa.

Farmers that produce their own seed or purchase seed from local consumer markets may unknowingly use disease contaminated seed in production. Few farmers have the necessary skills to determine whether their home produced seeds are free of diseases that can be seed transmitted. In most cases, observation alone is not sufficient to determine if seed is disease contaminated.

Seed purchased from rural consumer markets is more problematic with regard to disease contamination because farmers have no knowledge of the production history of this seed. Farmers typically make seed selection decisions at local markets on the basis of cultivar, physical appearance and price.

As indicated in an above section, most countries in sub-Saharan Africa that produce beans have a government owned entity that produces and distributes bean seed. However, little of this seed is expected to be produced under the conditions necessary for seed to be certified as disease free. The best disease control procedure that can be expected is disease monitoring throughout the plants' growth and reproduction periods and the discarding of seed grain produced on fields that have infestations of diseases that are seed transmitted. The extent that governmental seed organizations submit to this basic seed production practice is not known.

Given that most farmers use locally produced grain for seed and the widespread occurrence of diseases that can be spread through contaminated seed, yield loss due to contaminated seed could be an important consideration. Research on the chemical control of selected seedborne pathogens in Rwanda suggest that the economic returns from using uncontaminated seed could be significant (CIAT 1987; 1988). However, without more extensive research it is not possible to establish that disease contaminated bean seed is an economic problem over wide areas of sub-Saharan Africa.

The second issue regarding bean seed quality has to do with the physical condition of seed. The physical condition of seed can potentially affect yield through reduced seed germination or poor plant vigor in the early stages of plant growth if germination occurs.

The physical condition of bean seed is not expected to be an issue of economic importance in most bean producing areas of sub-Saharan Africa. The reason is that farmers have the skills necessary to appraise the physical condition of seed and are knowledgeable of its impact on seed germination and potential for reducing yield. Common strategies to cope with this problem are either to cull seed of poor physical quality or, if used, increase the seeding rate to compensate for the expected lower rate of germination.

The physical condition of seed may be of economic importance if farmers use mechanical equipment to plant beans. When mechanical equipment is used it is desirable that seed be of a known germinating quality in order to accurately gauge the desired plant distribution and overall population density. In addition, seed of low physical quality may result in a less than adequate performance of the mechanical planter; a consideration of importance on large farms.

Issues of Seed Quantity

As indicated above, the two important issues of bean seed quantity are the availability of seed of currently used and newly released cultivars. The supply and distribution of seed of currently used cultivars are well established in functioning markets, while that of newly released cultivars has yet to enter the market. The problems associated with the supply of currently used and newly released cultivars can thus differ significantly.

In an above section it was indicated that bean farmers secure most of their seed of currently used cultivars from their own production or from local markets. This market for seed is well established throughout sub-Saharan Africa and has successfully operated within a competitive environment for many years. A physical shortage of bean seed in this market would not be expected other than in extreme situations such as crop failure or civil strife.

New bean cultivars are normally released by research programs. In most countries a government parastatal or seed unit has the sole responsibility for producing and distributing seed of newly released cultivars. However, as with currently used cultivars, the effectiveness of these organizations in supplying seeds of newly released cultivars to small bean farmers is limited. The reason for this inability to supply seed is due to many factors but, in general, is not due to the lack of appropriate seed production technology. The technology to produce high quality bean seed is widely known and available.

Intervention in the Bean Seed Market

The purpose of this section is to identify strategies for intervention in the bean seed market that may hold promise for improving the supply and distribution of seed. In this regard, a question of the first order of importance to consider is whether intervention in the form of a public policy is economically justified. The criterion used here to determine if public intervention is justified will be the ability of the bean seed market to supply adequate quantities of acceptable quality seed at an affordable price to bean producers. If the market can perform this task, then intervention can not be justified on an economic basis.

The two bean seed issues of economic importance to farmers were the quality and quantity of seed. Given the available information, there is no evidence that either the quality or quantity of seed of currently used cultivars is inadequate under normal production conditions. Small farmers that produce for both subsistence and marketing dominate this competitive market. In most cases, grain sold for seed is priced identical to that sold for general consumption. Public intervention in this successfully operating seed market is not warranted.

The supply of newly released bean cultivars to small farmers is, however, believed to be a major problem. As indicated above, there is currently no mechanism to introduce seed of newly released cultivars into the marketing system other than through government parastatals or seed units. In general, these organizations have a poor performance record. The inability of these organizations to supply seed of newly released cultivars, coupled with the absence of specialized private sector seed firms, necessitates the development of new strategies if these cultivars are to be made available.

Public Policy and the Bean Seed Market

Public policies designed to intervene in the bean seed market can center on either the private or public sector. Specific targets within the private sector can be either the small farm sector or the large commercial seed firm. Targeting the public sector would involve either the creation of a publicly-owned firm or the organization of a seed unit, most likely within the ministry of agriculture.

Policies that put emphasis on the development of the private sector to supply the market for seed are generally preferable to policies that rely on public sector development. However, there may be good reason to believe that large private firms will not enter the market for bean seed in sub-Saharan Africa. The primary reason is that the market is undeveloped from a commercial point of view. Given the farm structure in which bean is produced, specialization in seed production may not be financially viable.

As noted above, it may be difficult to convince small farmers to purchase seed at a higher price than they will have to pay at local markets or in comparison to their opportunity cost for farm produced seed. The general rule-of-thumb for bean seed prices in developed countries is that certified seed is priced at a ratio of 3.5 to 1 when compared to local bean grain prices. In sub-Saharan Africa this ratio may have to be 4 or 5 to 1 if a private seed firm is to realize a profit. Small scale farmers can not be expected to pay premiums of this magnitude for bean seed.

Another issue of concern to private seed firms is that once introduced, farmers may be reluctant to continue seed purchases of a new cultivar in future seasons as grain will be available at a lower price in local markets. This is generally not a problem in developed countries as individual farmers require a large quantity of a known quality seed. However, it is not an uncommon practice for farmers in developed countries to use seed from grain produced the previous season if it is not disease contaminated.

These issues will also be of relevance to prospective small scale seed producers. In addition, small scale operations would probably require extensive governmental assistance, both technical and financial, to ensure successful entrance into the bean seed market. Schemes of this nature have been initiated by the government in Rwanda and, in general, have not been shown to be financially successful.

Intervention in the bean seed market through the public sector is generally regarded as a failure throughout sub-Saharan Africa when judged on the basis of the quantity of seed distributed to farmers. Therefore, policies that emphasize public sector involvement in the form of parastatals or seed units are unlikely to achieve the desired results.

The absence of a marketing mechanism that can efficiently produce and distribute the end products of agricultural research to farmers is believed to be a critical factor hindering the spread of agricultural technology in sub-Saharan Africa. The primary reason that these marketing mechanisms have not developed in either the private or public sector is the absence of appropriate financial incentives. If this is the case, then non-market methods that can distribute the results from agricultural research must be examined.

From a societal point of view, non-market methods to supply and distribute the results of agricultural research, such as a new bean cultivar, need not necessarily be uneconomical. If the social benefits that society receives through increased food supplies exceeds the social costs invested in developing, supplying and distributing the new technology, then the net social returns to society will be positive. From an economic point of view, the preferred non-market method will be the one that gives the highest net social benefits.

Many different non-market methods for introducing seed of newly released cultivars to farmers can be developed. In what follows is an outline of one such method that might hold promise in selected countries.

A Non-Market Example of Intervention in the Bean Seed Market

In 1987, the bean cultivar Carioca was released in Zambia. The agricultural research stations in the Central and North-Western Provinces elected to hasten the diffusion of the new cultivar by distributing Carioca seed free of charge to selected farmers. Four hundred farmers in a widely dispersed area were each allocated 2 kg of Carioca seed.

The objective of the project was to introduce the cultivar in the hope that farmers would retain and multiply the seed for continued future use if it was found to have acceptable characteristics. Once the seed had successfully entered farmers' normal marketing channels, then there would be no need for further introductions.

To determine the success of the method in distributing the Carioca seed, 64 of the 200 participating farmers in the Central Province were sampled in 1989; three seasons after the initial introduction. The results showed that 35 of the 55 farmers planting beans in 1989 were planting Carioca, 36 per cent of the surveyed farmers' total land area in bean was in Carioca and Carioca seed was given away 79 times and sold in markets 48 times (Grisley, 1990b). Forty-five per cent of the farmers surveyed knew, on average, of 3.5 other farmers who planted Carioca in the 1989 season. These results indicate the method for introducing the seed was a success.

An unattractive feature of this method is the cost incurred in seed purchases and distribution. However, these costs need not necessarily be prohibitive. Using a three-fold increase in the price of beans on the retail market in Lusaka, the cost of the Carioca bean seed distributed to the 400 farmers in Zambia amounted to US$ 792. This is a small sum to forgo when compared to the expected large social benefits gained from the distribution of the Carioca seed.

Two important features of the seed distribution method need to be emphasized. First, the distribution scheme concentrated on the supply side of market. Farmers were simply given a quantity of seed for which they had no previous demand. By providing the seed free of charge it was not necessary to create a commercial demand for the seed. As indicated earlier, creating a demand for bean seed of an unknown cultivar, which by definition includes all newly released cultivars, from small farmers could prove to be costly in most sub-Saharan African countries. Policies that target the supply side of the bean seed market may thus be more successful than those targeting the demand side.

The second feature is that seed was distributed to farmers who participate in a seed market that has been successful for a long time. As indicated above, the small farmer seed market is an extension of the overall grain market for beans. If the new cultivar is found to have desirable production, consumption, storage, and marketing characteristics, then the seed will be retained and distributed through established market channels. Building upon the success of a currently successful market can enhance the effectiveness of non-market seed distribution schemes.

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SUMMARY OF DISCUSSIONS

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Recommendations are not available to all farmers. Those farmers who have access to the information and want to follow recommendations, often can not do so as the recommended inputs are not available or are too expensive. It was concluded that farmers in the area are generally receptive to adopting new technologies if appropriate. Testing technologies under farmer conditions with inputs from farmers and extension workers will help in generating appropriate recommendations which will subsequently increase farmer adoption rates.

Kikoba

Shifts in weed populations and species as a function of cultural practices, both on-farm and on-station, were discussed. The survey is still on-going, and preliminary findings must be substantiated with additional data. Bean yield loss due to weed species and population, crop rotation practised on the study plots and how weeds were controlled on the previous crops should be taken into consideration and their effects on the study crop carefully analyzed and discussed.

Kisakye and Ugen-Adrogu

Surveys were conducted to identify farmer-perceived constraints to bean production and experiments were performed to determine which factors are responsible for bean yield loss. A concern was voiced from the floor about the unusually low yield obtained from some of the experimental plots. Since the experiments were not carefully controlled (farmers were asked to follow their own cultural practices), crop density might not have been optimal. Pre-plant seed treatment with fungicides provided only partial disease control; this is to be expected as seed treatment does not protect plants from later infestations in the field. There was a lengthy discussion of the rationale for conducting trials using chemical fertilizer, as these are generally not available or affordable by most African farmers. These trials are rationalized on the basis that there are no existing recommendations on fertilizer use for bean production by large farmers and commercial producers. Small farmers could benefit from the application of manure/compost on their bean fields.

Tenaw Workayehu

Poor yields of bean in the work area were attributed to factors such as late planting, poor soil fertility and unimproved cultivars. It was established that June planting is better than July planting; however, as bean is planted after maize, farmers' option of planting bean much earlier is limited. Researchers are considering introducing early maturing maize cultivars to address this problem. The lack of response to added fertilizer was also discussed. It was suggested that the researchers may obtain better response by applying fertilizers in the furrows before planting. To the extent possible, all trials should be subjected to benefit/cost analysis.

Where soil pH is low, lack of response to P may result from slow release from low-P sources (for example, rock phosphate) or tying up of the P where it is released quickly.

Sieber

The mulching material was not incorporated into the soil. The validity of the observation that pest incidence is greater with minimum tillage will have to be established by research staff. The burden of the choice between feeding crop residues to livestock and using them for mulching lies with the farmer.

In the mulching experience, it was observed that mulch decomposition may upset the soil nutrient balance. Such imbalance may be reduced by termites, which feed on the mulch and may even aid infiltration. Mulched plots stored a lot of water below the root zone. There is need for agroforestry in this area.

Wortmann and Ugen-Adrogu

The fertilizer was applied to maize but bean also benefited as it was planted in close proximity with maize. The experimental design was changed between seasons in order to gain better understanding of the system.

For the introduction of climbing bean in Uganda the companion crop (maize) may add another element in the diet since maize is not normally grown in this area, where banana is the main intercrop component. The farmers were informed and involved from the onset of the demonstration. The raised their points before agreeing to participate.

Govinden and Ismael

Economic analysis has been done on other crops and cropping systems and will be applied to bean systems.

Ochwoh and Zake

It was noted that soil problems, especially those related to pH, occur in various parts of the region. Screening especially for low pH tolerant genotypes is necessary. In very acidic conditions, nodulation was absent, plants were stunted and root development affected. These features may be useful as criteria in selecting for tolerance to acidic conditions. It is planned to evaluate materials considered to possess tolerance to acid conditions but a start has been with local cultivars.

Kidane Georgis

Where no weeding was practised, grain yield increased with increasing seeding rate. In Ethiopia, 92 per cent of farmers do not weed the bean crop.

It may be unattractive to grow bean with 40 per cent yield reduction due to lack of weeding and high percentage reductions due to other factors taken singly. There has been no attempt to correlate disease incidence with yield but it would be worthwhile.

Although the added cost of extra seed required to give weed suppression effects appears justified in economic terms, it has not been examined critically.

Weed masses were less with bean lines of plant type IIIa than with those of growth habit II, indicating a relationship between morphological characteristics and ability to suppress weeds.

Muthamia

Although herbicides are expensive, even medium to small scale farmers are anxious to begin using them.

Much data were obtained from the trial, but time does not permit their presentation here. Costs are available and will be subjected to full financial and economic analysis. Weed density and composition may have differed from those on farmers' fields at the start of the experiment because of land utilization histories. The work needs to be repeated on farmers' fields to sample real farmers' field production environments.

Kisakye and Ugen-Adrogu

Up to ten entries can be accommodated in on-farm variety trials. The number included depends on the number offered. If too few are included, promising cultivars may be omitted. Ten farmers from each district and five from each county are sufficient to draw conclusions about cultivar performance.

Grisley

CIAT has recently distributed a new bean line to farmers without previously evaluating it on farm and it has been very popular.

In developed countries, seeds are sold at up to 73 times the grain price. In Africa, farmers cannot afford such prices, so seed companies consider seed production unprofitable. Farmer attitudes may change as they realize that good quality seed produces improved yields. There is a need to work on demonstration plots through extension agencies to ensure that seeds are sown and not consumed. Though demonstrations are primarily to extend improved technology, they can also serve as vehicles for seed distribution.

General

A question was raised if the FSR methodologies used in the member countries are more or less the same. It appeared that the major components of FSR methodology are retained by all programs. The use of diagnostic surveys to prioritize farmer problems and production constraints is a common phenomenon.

The importance of multidisciplinarity of survey teams is not shared by all participants. It is believed that survey procedures also provide opportunities for researchers to interact closely with the farmers and extension workers. Conducting surveys and on-farm trials is expensive and may not be sustainable without donor support.

SESSION VII: CLOSING SESSION

REGIONAL PRIORITIES FOR RESEARCH

Regional Research Projects

The opportunity provided by Session II for reviewing progress on regionally-supported collaborative research projects was appreciated by participants. More discussion time should be allowed for this purpose in future workshops.

Research in some projects was seen to be restricted to a single country. All projects should become fully regional in nature, often by following an agroecological approach that crosses national boundaries.

The following priority topics for new regional projects were identified:

a) Agronomy warrants more attention, including the areas of
   - soil fertility management
   - genetic tolerance to low phosphorus soils
   - use of rock phosphate
   - management of soil acidity and alkalinity.

b) Research on non-formal seed dissemination, to ensure that seed of new varieties reaches large numbers of small producers.

c) Development of more productive cropping systems based on the introduction of climbing beans.

d) In crop protection, research on root rots is needed, as well as increased attention to beanflies.

Workshop participants recommended that the regional project approach be intensified. Potential collaborators from interested countries should work together in drawing up the initial proposal, indicating their specific and joint responsibilities. Collaborators should harmonize their experimental designs, including methods of data collection and analysis. Regional training could facilitate this process.

Research Facilities in the Region

While shortages of equipment can limit the scope of research in some areas, most participants believed that much of the most useful work can be carried out with modest means. For example, good conditions for inoculating germplasm lines in screening studies can be obtained very economically by the use of atomisers in screenhouses. CIAT itself does not use growth chambers for this type of work, and recommends avoiding equipment that is very sensitive to interruptions in electrical supply.

Universities in the region are sometimes well placed to offer research facilities for use by national research programs. An example is Makerere University's acquisition of facilities for conducting ELISA tests for plant viruses, under the regional project on BCMV, which is intended to provide a service to any country in the region. While the larger national agricultural research institutions may be able to contemplate self-sufficiency in research equipment, financial considerations are likely to continue to favour regional collaboration. Nowhere is this need more evident than in soil analytical laboratories, which are expensive to maintain and generally in poor condition.

National Program Research

Ways of improving the quality of research in national programs were discussed. Still more effort is required to achieve the necessary level of interdisciplinarity; in particular, socio-economic aspects are often lacking. Social scientists are not available to join bean teams in some countries, but other ways of obtaining input in this area can usually be found.

Although the amount of on-farm research involving bean has increased since the last regional workshop in 1987, it is still not enough. In particular, data on crop losses under farmers' conditions are needed for improving the setting of priorities.

In the area of crop protection, greater emphasis on epidemiological studies will be needed if pest and disease management strategies are to be designed.

Observations on the relative merits of abandoning or continuing with research on pesticides and fertilizers led to a lively debate. In Africa we need to avoid falling into the dependence upon agrochemicals that characterizes much of Latin American agriculture, where farmers in some areas make up to twelve insecticidal applications to a bean crop. Feasible alternatives to agrochemicals need to be sought, in the interests of sustainable development. Fertilizer use needs to be viewed within an integrated crop management system, rather than being developed merely for a bean component of that system. Scarce research resources should be used in accordance with carefully developed priorities. Since fertilizer research can lead fairly rapidly to research recommendations, this can be undertaken most appropriately when research funds are readily available; in times of scarcity, on the other hand, the longer term research needed to develop sustainable systems of production deserves continuity of support.

Making decisions on resource allocation to research is a national prerogative and responsibility. However, the regional program also needs to make its research priorities, and will continue to try to complement national efforts by taking a medium term approach and by tackling strategic and riskier topics that may have high potential payoff.

Communicating the Results of Research within the Region

Participants endorsed the regional program's approach to workshops. This consists of multidisciplinary workshops held every two or three years, such as this one, supplemented by specialist workshops and working group meetings at the pan-Africa level in collaboration with other regional bean programs. The quality of presentations at this workshop had been noticeably higher than in the previous one, with more data and better use of overhead transparencies by speakers.

Future multidisciplinary workshops should include extensionists and address the vital topic of technology transfer. More time is needed for discussing regional research projects, possibly at the expense of the number of papers presented, and the field trip should be reinstated.

The regional program was encouraged to redouble its efforts to facilitate the exchange of national reports among countries. It also plans to distribute an annual regional report among collaborators. Reviving the *Phaseolus Bean Newsletter for Eastern Africa* (formerly published by KARI) was considered to be important and the regional coordinator welcomed the recent offer made by the Director of KARI's National Horticultural Research Station at Thika.

CLOSING ADDRESS

Mrs. M.N. Wabule

Assistant Director, Kenya Agricultural Research Institute, Nairobi, Kenya

CIAT representatives, Regional Programme Coordinator, Participants, Observers, Invited Guests, Ladies and Gentlemen,

I am delighted to be here with you to mark the end of the Second Regional Workshop on Bean Research in Eastern Africa.

I am pleased to note that during the last days, you have deliberated on very important issues related to bean production, namely genetic improvement of beans, agronomy and economics of bean production, crop protection and regional collaborative research.

I am confident that as result of your deliberations, you have come up with valuable recommendations which I believe will guide bean research in the region. I hope the regional scientists will implement these recommendations for the benefit of the farmer.

Allow me, Ladies and Gentlemen, to stress the need to integrate your bean research programmes with other disciplines such as the national cereal programmes to avoid isolated programmes. In a recent workshop on farming systems and the recently concluded farming systems approach workshop in Nyeri, a national programme on FSA has been agreed upon. It is therefore our wish in KARI that we all play our part to ensure FSA takes off.

I note with great satisfaction that CIAT and CIMMYT have already played a key role in formulating similar guidelines as noted in "The Planning Stage of On-Farm Research - Identifying Factors for Experimentation", which I believe was published last year. May I request CIAT to assist in the informal training of our scientists by exposing them to the procedures stipulated in this plan.

CIAT has in the past played a big role in the training of our scientists. I thank them for this and request them to continue to support our national grain legume programme. CIAT's rich germplasm and information could benefit our scientists greatly.

I appeal to CIAT to facilitate the exchange of germplasm and encourage visits by the scientists in the entire region.

Bean is a major food crop in Kenya as you already know. The bean programme does not have the external funding which other programmes enjoy. Your support therefore will go a long way in improving bean production in this country.

To the scientists who have participated in this workshop, it is my sincere hope that the contacts you have established during the workshop will be maintained and strengthened to enhance future collaboration and scientific exchange in the region.

Finally, on behalf of the Kenya Government and KARI, I take this opportunity to thank CIAT and other organizations for their support in organizing and sponsoring the workshop. May I also thank the KARI staff who were involved in the organization and the authors of the various papers for the effort they put in their preparation.

To our visitors I must say it has bean a great pleasure to have you here with us and I would like once more to invite you to visit Kenya whenever you can. *Karibu tena*!

With those few remarks, Ladies and Gentlemen, it is now my pleasure to declare the Second Regional Workshop on Bean Research in Eastern Africa officially closed.

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