SECOND MEETING OF THE
PAN-AFRICA WORKING GROUP ON BEAN ENTOMOLOGY

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PREFACE

This publication records the proceedings of the Second Meeting of the Pan-Africa Working Group on Bean Entomology. The first meeting was held in 1989 and at that meeting priorities for bean entomology research in Africa were set and sub-projects were developed accordingly for research on various problems. The send meeting was held to review progress made since 1989 to review priorities in the light of recent achievements and to refocus on new areas of research as necessary.

This is the twenty-fifty volume in the Occasional Publications Series that serve research on beans (*Phaseolus vulgaris* L.) in Africa. These publications series form part of the activities of the Pan-African bean research network, which aims 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 independent research projects, for the Great Lakes region of Central Africa, for Eastern Africa and, in conjunction with SADC, for the Southern Africa region.

Working documents will include bibliographies, research reports and network discussion papers. These publications are intended to complement an associated series of Working Proceedings.

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).

Further information on regional research activities on common beans in Africa, and additional copies of this publication, are available from:

Pan-Africa Coordinator, CIAT, P.O. Box 23294, Dar es Salaam, Tanzania.

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

WORKSHOP SERIES

No. 1. Beanfly Workshop, Arusha, Tanzania, November 16-20, 1986.

No. 2. Bean Research in Eastern Africa, Mukono, Uganda, June 22-25, 1986.

No. 3. Soil Fertility Research for Bean Cropping Systems in Africa, Addis Ababa, Ethiopia, September 5-9, 1988.

No. 4. Bean Varietal Improvement in Africa, Maseru, Lesotho, January 30 - February 2, 1989.

No. 5. Troisieme Seminaire Regional sur l'Amelioration du Haricot dans la Region des Grands Lacs, Kigali, Rwanda, 18-21 Novembre 1987.

No. 6. First SADCC/CIAT Regional Bean Research Workshop, Mbabane, Swaziland, October 4-7, 1989.

No. 7. Second Regional Workshop on Bean Research in Eastern Africa, Nairobi, Kenya, March 5-8, 1990.

No. 8. Atelier sur la Fixation Biologique d'Azote du Haricot en Afrique, Rubona, Rwanda, Octobre 27-29, 1988.

No. 9. Actes du Quatrieme Seminaire Regional sur l'Amelioration du Haricot dans la Region des Grands Lacs, Bukavu, Zaire, 21-25 Novembre, 1988.

No. 10 National Research Planning for Bean Production in Uganda, Makerere University, Kampala, Uganda, January 28 - February 1, 1991.

No. 11 Proceedings of the First Meeting of the Pan African Working Group on Bean Entomology, Nairobi, Kenya, 6-9 August, 1989.

No. 12 Ninth SUA/CRSP Bean Research Workshop, and Second SADCC/CIAT Regional Bean Research Workshop. Progress in Improvement of Common Beans in Eastern and Southern Africa, Sokoine University of Agriculture, Morogoro, Tanzania 17-22 September, 1990.

No. 13 Virus Disease of Beans and Cowpea in Africa, Kampala, Uganda, January 17-21, 1990.

No. 14 First Meeting of the SADCC/CIAT Working Group on Drought in Beans, Harare, Zimbabwe, May 9-11, 1988.

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

No. 16 Cinquieme Seminaire Regional sur l'Amelioration du Haricot dans la Regional des Grands Lacs, Bujumbura, Burundi, 13-17 Novembre 1989.

No. 17 Sixieme Seminaire Regional sur l'Amelioration du Haricot dans la Region des Grands Lacs, Kigali, Rwanda, 21-25 janvier 1991.

No. 18 Conference sur le Lancement des Varietes, la Production et la Distribution des Semences de Haricot dans la Region des Grands Lacs, Goma, Zaire, 2-4 Novembre 1989.

No. 19 Recommendations of Working Groups on Cropping Systems and Soil Fertility Research for Bean Production Systems, Nairobi, Kenya, 12-14 February 1990.

No. 20 First African Bean Pathology Workshop, Kigali, Rwanda, 14-16 November, 1987.

No. 21 Soil Fertility Research for Maize and Bean Production Systems of the Eastern African Highlands - Proceedings of a Working Group Meeting, Thika, Kenya, 1-4 September 1992.

No. 22 Actes de l'Atelier sur les Strategies de l'Amelioration Varietale dan la Region des Grands Lacs, Kigali, Rwanda, 17-20 Janvier 1991.

No. 23 Proceedings of the Pan-Africa Bean Pathology Working Group Meeting, Thika, Kenya, May 26-30, 1992.

OCCASIONAL PUBLICATIONS SERIES

No. 1. Agromyzid Pests of Tropical Food Legumes: a Bibliography.

No. 2. CIAT Training in Africa.

No. 3A. First African Bean Yield and Adaptation Nursery (AFBYAN I): Part I. Performance in Individual Environments.

No. 3B. First African Bean Yield and Adaptation Nursery (AFBYAN I): Part II. Performance Across Environments.

No. 4. Assessment of Yield Loss Caused by Biotic Stress on Beans in Africa.

No. 5. Interpretation of Foliar Nutrient Analysis in Beans-- the Diagnosis and Recommendations Integrated System.

No. 6. The Banana-Bean Intercropping System in Kagera Region of Tanzania--Results of a Diagnostic Survey.

No. 7. Bean Stem Maggot Research Methods: Training Course at Bujumbura, Burundi, 1-8 November, 1991.

No. 8. On-farm Storage Losses to Bean Bruchids and Farmers' Strategies: A Report on a Travelling Workshop in Eastern/Southern Africa, 16 September - 3 October, 1992.

REPRINT SERIES

No. 1. Bean Production Problems in the Tropics: Common beans in Africa and their constraints.

No. 2. Bean Production Problems in the Tropics: Insects and other pests in Africa.

No. 3. Diagnosis and Correction of Soil Nutrient Problems of Common Bean (*Phaseolus vulgaris*) in the Usambara Mountains of Tanzania. Journal of Agricultural Science, Cambridge (1993), 120, 233-240. Copy right 1993 Cambridge University Press:

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SUMMARY

OBJECTIVES

In 1989 the first meeting of the Pan-Africa Working Group on Bean Entomology brought together entomologists from nearly all the major bean growing countries in Africa with the following primary objectives:

1. to review progress made in bean entomology in Africa and elsewhere.
2. to identify priorities for research in bean entomology in Africa.
3. to formulate research linkages among scientists through the development of regional collaborative research sub-projects.

At that meeting the following were identified as key pests that constrain bean productivity within Africa:

1. Bean stem maggot (*Ophiomyia* spp.)
2. Bruchids (*Zabrotes subfasciatus* and *Acanthoscelides obtectus*) and
3. Aphids (as vectors of viral diseases).

Collaborative Research Sub-projects were recommended on these pests and subsequently were approved by the Steering Committees and executed by National Programme Scientists with technical support from the regional entomologist and, in some cases, from an entomologist at CIAT HQ.

The purpose of this Second Meeting was to:

1. review progress and achievements made through the sub-projects in solving the problems originally identified.
2. review the prioritization of key pests and the focus on the areas of research.
3. allocate resources for research and development of solutions for priority problems.

METHODOLOGY

The methodology used was a blend of the "Project Planning by Objective" (PPO or ZOPP) and "The Planning Stage of On-Farm Research : Identifying Factors for Experimentation" by Tripp and Wooley, 1989.

The steps followed were:

1. Problem identification.
2. Setting priorities among problems.
3. Identification of causes and effect.
4. Identification of solutions and priority setting among solutions.
5. Project design and documentations.
6. Resource allocation for research on priority problems.

RESULTS

Key Problems

A total of six pest species and species complexes were identified as constraining bean productivity in different parts of the region. Out of these the following priority list was developed :

1. Bean stem maggot (Beanfly) (*Ophiomyia* spp.)
2. Bruchids (*Acanthoscelides obtectus* and *Zabrotes subfasciatus)*
3. Foliage beetle (*Ootheca* spp.)
4. Aphids (Aphidae in general)
5. Pod bugs (various Hemiptera and Coreidae)
6. Thrips (*Megalurothrips* spp. *Sericothrips* spp. and *Thrips* spp.

Several other pests were considered as being of localized importance e.g. leafminers in Mauritius and whiteflies in Sudan. In such cases the individual national programmes were encouraged to tackle them directly and to request assistance from the regional programmes and/or the regional entomologist as necessary.

Research and development

The following areas of research were identified for future sub-projects focus.

Bean stem maggot

The group felt that there is now a reasonable understanding of the pest distribution, biology and ecology. Also, there is now a considerable array of strategies developed for BSM management. Emphasis should now be placed on:

1. Screening for sources of resistance and development of resistant cultivars.
2. Creation of farmer awareness of the BSM problem through the development of extension documents as well as farmer seminars.
3. Farmer, extension and researcher collaboration in trials for technology development, transfer and adoption.

Bruchids

The group acknowledged that good sources of resistance to *Z. subfasciatus* are now available from CIAT and that good progress has been made toward the development of a variety of control methods. Emphasis should now be placed on:

1. Incorporation of *Zabrotes* resistance into adapted or local varieties.
2. Dissemination of newly developed bruchid management technologies through farmer, extension and researcher collaboration in evaluation of technology.
3. Development of IPM strategies especially for *Acanthoscelides* to which resistant varieties are not yet available.

Aphids

The group recommended that the sub-project on differential transmission of BCMV strains by different aphid species should be transferred to the BCMV (Virology) sub-project at Sokoine University of Agriculture, Morogoro since what is left to be done is more in virology than entomology. Any new sub-project on Aphids should focus on:

1. Development of strategies for the management of Aphids as direct pests, especially during the dry seasons.

Foliage beetles, thrips and spiny brown bugs

The group acknowledged that there is insufficient knowledge about theses pests[1] and that initial focus should be on survey of literature to determine what is presently known about them. Future research should focus on biology and ecology: i.e. study the environmental factors, natural enemies and alternate hosts as they influence their population dynamics.

Allocation of resources

The working group then recommended that resources, when available for bean entomology research and development of control strategies, be allocated as follows:

1.	BSM	25%
2.	Bruchids	20%
3.	Foliage beetles ((*Ootheca* spp.)	20%
4.	Aphids	10%
5.	Spiny brown bugs	7.5%
6.	Thrips	7.5%.

Ten percent of the available resources were reserved for country specific problems, such as white flies (*Bemisia tabaci*) in Sudan and leafminers (*Liriomyza* spp.) in Mauritius.

It is the expectation of the Pan-Africa Working Group on Bean Entomology that future sub-project proposals will reflect these priorities and that Steering Committees will consider proposals for bean entomology research and development in the light of these identified priorities.

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1 Mrs Lilian Pomela is now engaged in a PH.D. study on spiny brown bugs on beans in Lesotho with financial and technical support from the SADC/CIAT Regional Bean Programme.

HOST PLANT RESISTANCE AND CULTURAL STRATEGIES FOR BEAN STEM MAGGOT MANAGEMENT

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ABSTRACT

Various control tactics are being studied for incorporation in an overall strategy for the management of bean stem maggot (*Ophiomyia* spp.) in beans. These include host plant resistance, cultural practices and chemical pesticides. Moderate sources of resistance have been identified and these are in use in breeding programmes to incorporate resistance in local varieties. An evaluation of various cultural methods such as earthing-up, mulching and increased fertility indicate that mulching of field plots reduced plant mortality from BSM attack by 38% compared to the control and that mulching combined with increased soil fertility reduced plant mortality even further. Foliar application of certain botanical pesticides such as alcohol extract of neem seed powder and aqueous extract of *Tephrosia* leaves also reduced infestation by bean stem maggot and increased yields. Field evaluations of the use of these and other tactics in an integrated system in small scale farmers' situation are now underway.

INTRODUCTION

Bean Stem Maggot (beanfly) (*Ophiomyia* spp.) is considered the principal insect pest that constrains bean productivity in many of the crop's growing environments in Africa and Asia. Three species: *O. phaseoli*, *O. spencerella* and *O. centrosematis* are known to attack the crop but their distribution and importance vary with location and season. The nature of damage caused by the different species, however, is quite similar: attacked young plants wilt and die. In older plants the stems get swollen, crack and lodging may ensue. Damage is most severe when seedlings are attacked and in stress situations, such as may result from soil infertility, drought or disease, BSM attack often leads to total crop failure.

Various control methods for bean stem maggot (BSM) in beans have been proposed: these include; chemical application, (notably Lindane or Endosulfan) seed dressing (Lays and Autrique, 1987), cultural practices e.g. earthing-up (Moutia, 1944), increased plant population (Abate, 1990), change of sowing dates, etc. The efficiency of these methods vary with time of application and environmental conditions, and in some communities some of these methods may be incompatible with traditional practices. Sources of resistance exist in various germplasm accessions but there were not adequate utilized at the farm level.

A principal objective of the entomology network in the CIAT regional bean programmes is to develop IPM strategies (with adequate flexibility) for use by resource poor bean growers. This paper reports on progress made in identifying components for possible IPM strategies for the bean stem maggot.

Host plant resistance

Over three thousand germplasm accessions and CIAT breeding lines comprising largely of materials in store at the Selian Agricultural Research Institute, Arusha, Tanzania have been screened for

BSM resistance. The methodology used is based on infestation levels and plant mortality due to BSM attack. As BSM population (activity) vary over time through the season, these populations were monitored through trapping and inspection of field plants and test entries were sown in time to coincide with pest infestation of ca. 4 insects/plant. plants were monitored regularly for infestation and damage. BSM infestation levels as well as plant mortality was used as the principal criteria for resistance or susceptibility. Resistance levels in the test entries were categorized using the distribution of the mean and multiples of standard deviation. Analyses of variance, as well as, comparisons with resistant and standard checks were used to select for resistance in subsequent evaluations.

Results from the preliminary evaluation indicated that only low to moderate levels of resistance existed in this set of materials (Figure 1). The performance of the materials in the group categorized as moderately resistant was compared against the "resistant check" (Lyamungu 85 treated with endosulfan) (Table 1). While the susceptible check (Lyamungu 85 untreated) suffered ca. 34% mortality due to BSM, several of the test entries (G 12670 x G 4727-2, 7126/DR 670 x G 5701/D 145, Montcalm 4, 86 EP 5022-B and TMO 126) performed close to the "resistant check".

Figure 1. Relative levels of resistance in a set of germplasm evaluated at Selian, Arusha. (R - resistant; MR - moderately research; INT - intermediate; MS - moderate susceptible; S - susceptible).

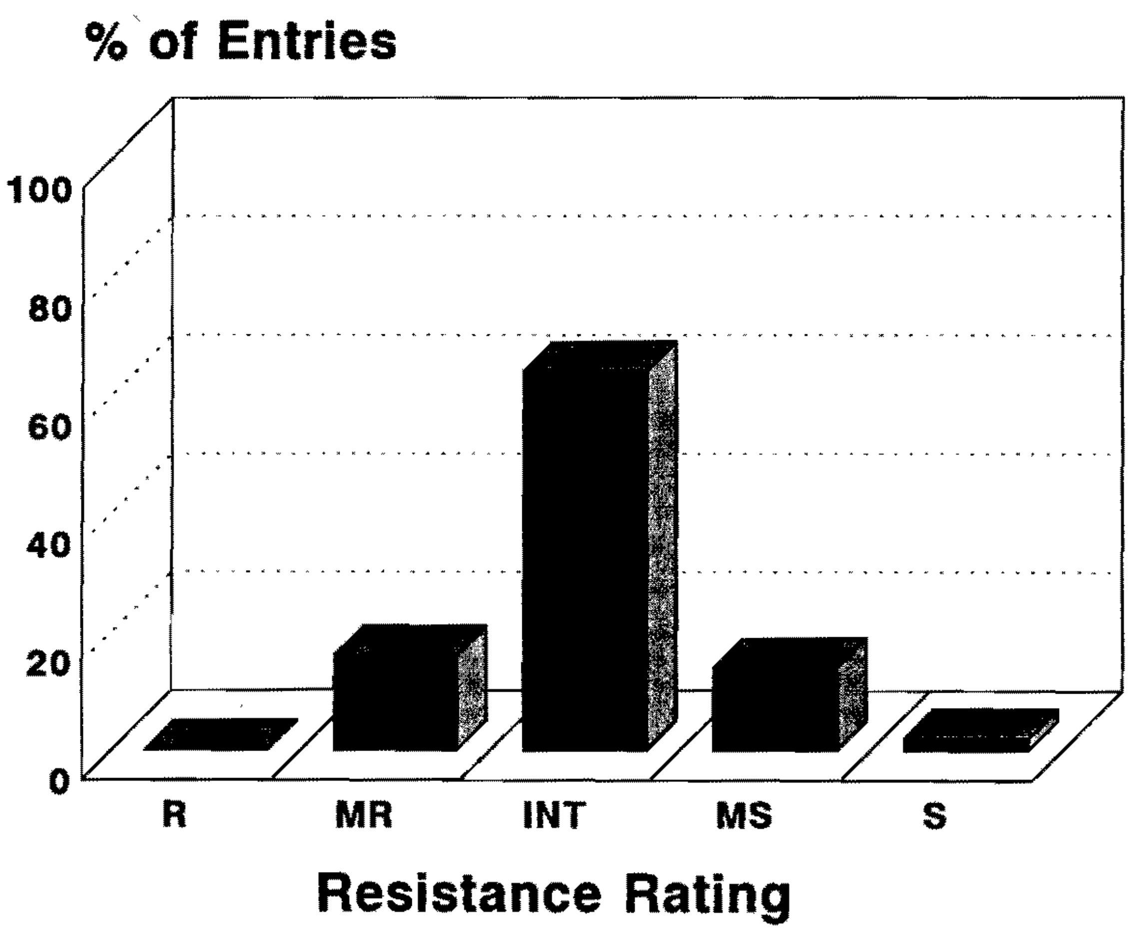


Table 1. Performance of accessions classified as resistant in a preliminary evaluation in comparison with "resistant" and susceptible checks.

Accession Name	Std at Emer.	Total Seed Mortality	BSM/ Dead Plant at 6 WAE	% Total Mortality	% Mortality due to BSM
G 12670 x G 4727-2	22.0	0.7	0.0	3.3	3.3
7126/DR 670 x G 5701/D 145	37.5	1.5	4.0	4.4	4.4
Montcalm 4	21.0	1.5	2.5	5.6	5.6
G 13936 x A 487	29.0	2.0	4.3	7.2	7.2
TMO 237	25.5	2.0	3.9	7.5	7.5
86 EP 5022-B	27.5	2.5	4.5	8.7	5.3
81 CC - 62 x Horse Head	40.0	3.5	2.3	8.9	7.7
Royal Red x Canadian Wonder-2	22.0	3.0	3.6	10.3	8.6
TMO 126	31.5	3.5	6.1	10.8	3.4
BAT 1337 x G 6592-2	34.0	4.0	0.0	12.0	12.0
ACV 8331	23.5	3.5	4.5	15.0	15.0
Checks					
Lyamungu 85	37.2	16.5	8.3	44.4	34.4
Lyamungu 85 + Endosulfan	37.5	1.8	3.0	4.9	4.0
ZPv 292	38.0	10.8	3.3	28.9	23.4
Trial Mean	28.2	9.3	4.6	33.4	29.6
LSD .05.	9.4	9.7	5.0	32.6	22.6

BSM resistance reconfirmatory nurseries (BRRN)

These materials are designed to test certain putative sources resistance across contrasting environments and BSM species populations. BRRN-1 (Table 2) comprised 10 entries consisting of local landraces, CIAT breeding lines and germplasm accessions was evaluated at seven sites in eastern and southern Africa and south Asia (Table 3). The parameters for evaluation were: (i) plant mortality; (ii) BSM infestation levels; (iii) plant vigour; (iv) prolificacy of adventitious rooting; and (v) stem cracking. Higher infestations levels were observed at Shanhua (Taiwan) and Gisozi (Burundi) and therefore more emphasis was placed on the data from these locations. Ikinimba was resistant at Gisozi and higher altitude environments but susceptible in other locations probably because of poor adaptation to lowland areas (Figure 2). ZPv 292 was resistant in all locations except Gisozi, again perhaps due to poor adaptation. BAT 1373 showed resistance in nearly all locations. Other entries showed resistance at specific locations (e.g. G 5773) at Awassa). Some of these material are now in use in breeding programmes to incorporate resistance into other backgrounds. The BRRN-2 had entries with higher levels of resistance but most of them had the I-gene and were highly susceptible to "Black root" and were therefore not distributed. However, one entry "Sinon" showed good resistance to BSM and "black root" and has been added to BRRN-1.

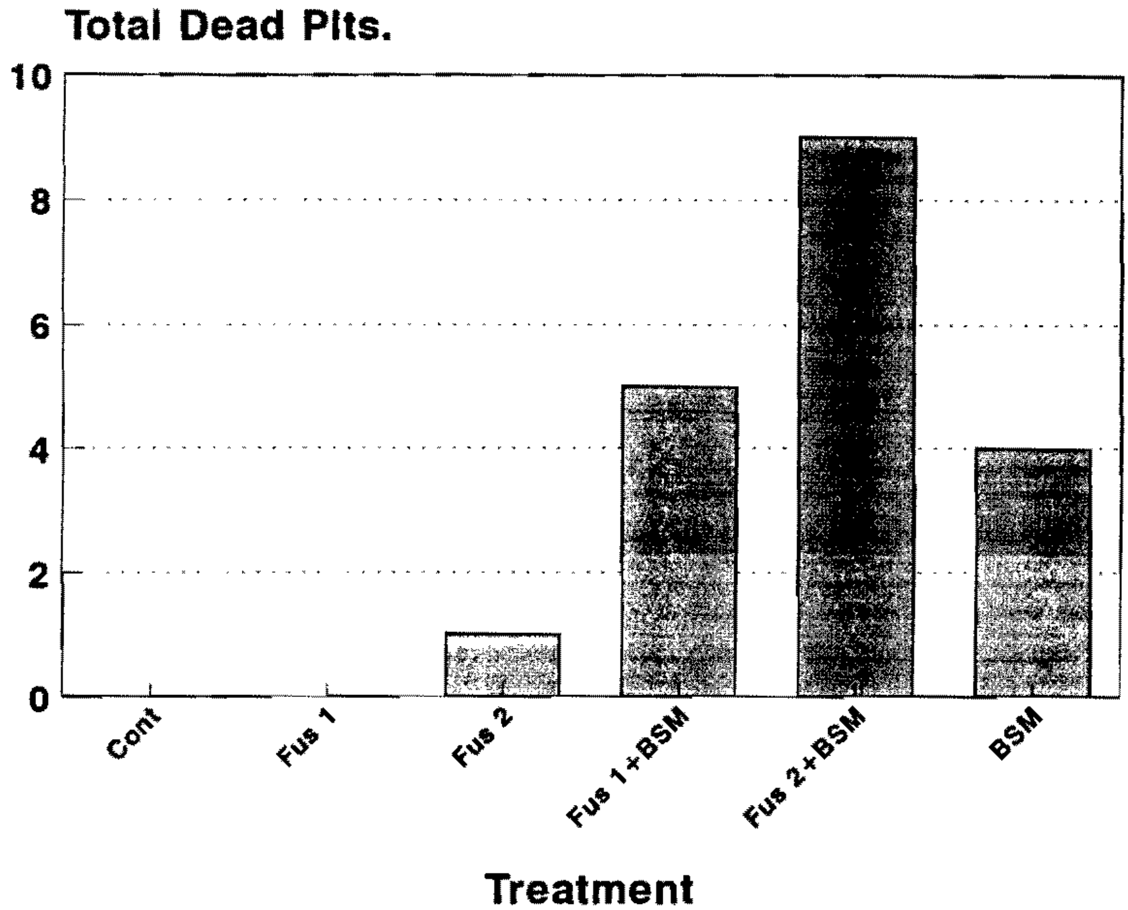
Table 2. Entries in the BSM Resistance Reconfirmatory Nursery-$_1$

Line	Origin	Pedigree	Where tested	Seed colour	Seed size
G 2005	Guatemala	PI 310739	Ethiopia	Black	Small
G 2472	Mexico	PI 313343	Ethiopia	Black	Small
G 3844	U.S.A.	I-1162	Ethiopia	White	Medium
G 5253	Brazil	Bzl 1198	Ethiopia	Black	Small
G 5773	Colombia	-	Ethiopia	Black	Small
EMP 81	CIAT	-	Ethiopia	Black	Small
Ikinimba	Burundi	Landrace	Burundi	Black	Small
BAT 1373	CIAT	IN 17 x Sel 72	Burundi	Black	Small
A 74	CIAT	A 30 x G 4017	Zambia	Yellow	Medium
ZPv 292	Uganda	Landrace	Zambia	Purple	Medium

Table 3. Effect of various plant extracts on BSM activity plant damage and yield.

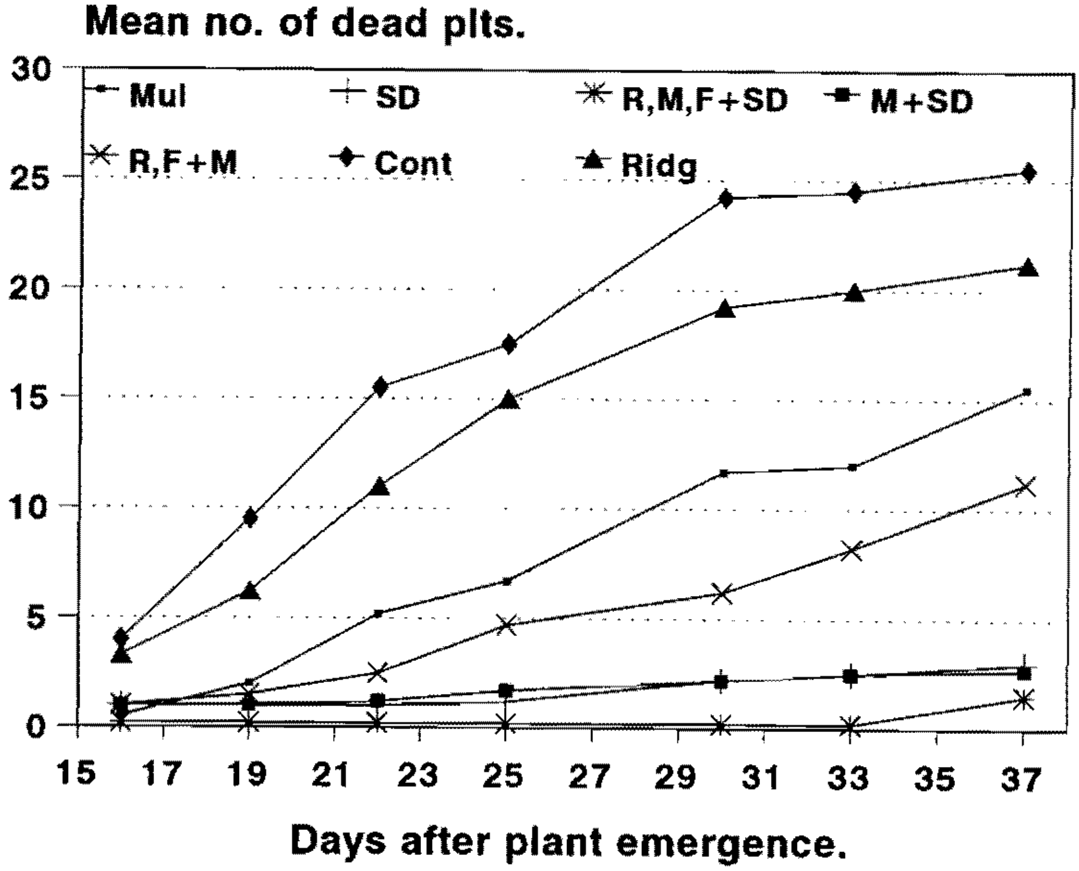
Treatment	Ovip./feeding punctures	BSM/Plant (R5)	Cum BSM score	Total plant loss	Yield/plot (g)
Control	90.3 a	7.3	429.5	38.3	190.5
Maize Juice	88.3 a	9.5	376.3	41.5	177.3
Teph	47.7 b	6.2	300.3	32.7	232.3
NSE W	85.0 a	7.8	323.5	35.5	173.8
NSE AL	43.2 b	7.3	239.7	25.0	273.8
Endo.	94.8 a	3.5	65.8	7.2	338.0

Figure 2. BSM and root disease interaction on severity of damage.Interaction between BSM and soil-borne pathogens.



Our other studies show some strong interactions between BSM infestation and root disease infection on the severity of damage expression in certain locations. This was confirmed in a screenhouse study where bean plants were grown on soil infected with *Fusarium* spp. and exposed to BSM when plants were in the V_1 stage in a factorial design, and in field studies at several locations across northern Tanzania. Treatments in the field included exposure to, and protection from BSM and/or root disease attack using chemical pesticides. The results suggest a synergistic interaction between BSM and some soil-borne pathogens in the extent of the mortality caused to bean plants. Mortality was higher where the two organisms occurred together (Figure 3), even at low BSM population levels and the current hypothesis is that feeding and oviposition activities by the adult BSM create avenues that facilitate entry by the pathogen. To remove this compounding interaction, it is recommended that test plants be protected against such organisms so that performance against BSM will be clearer. However, since these organisms frequently occur together in many field situations, it is essential that multiple resistance be developed to BSM and soil-borne pathogens together.

Figure 3. Effect of cultural practice on BSM induced plant mortality.



Crosses between resistant accessions and adapted cultivars have been initiated at CIAT and in Tanzania through a Regional Collaborative Research Sub-project. Early results indicate that the resistance is transferable.

Cultural control

Various cultural control methods such as time of sowing, crop rotation, planting density, earthing-up, mulching etc. that are used by farmers were considered and some of these were evaluated for their potential in BSM damage control. The treatments were : (i) Earthing-up (piling of soil at the base of plants during first weeding (2 3 WAE)). (ii) Mulching of test plots with chopped banana leaves before plant emergence; (iii) Enhanced soil fertility - application of inorganic fertilizer at local recommended rates; (iv) Endosulfan seed dressing at 5g of 47% WP per kg of seed; (v) Control (seeds sown on the flat without any of the above treatments) and various combinations of the above treatments. Plants were monitored frequently for the effect of treatment on BSM infestation, plant mortality and subsequent yield.

In general none of the treatments affected plant emergence significantly even though mulching seemed to induce etiolation of seedlings. Mulching also induced some yellowing of the leaves but these conditions disappeared before flowering. Nearly all plants were infested and plant mortality started as early as 16 days after emergence (DAE) and continued until ca. 40 DAE, after which mortality was significantly reduced (Figure 4). In this trial, mean BSM infestation was moderate (4 insects per plant) (Table 4) and subsequent plant mortality was also moderate (11 plants per plot) across the trial. Treatments with chemical seed dressing had the most effective control of BSM, among the non-chemical treatments, mulching was the only one that reduced plant mortality below the control even though all the other treatments reduced plant mortality below the control even though all the other treatments reduced mortality somewhat. Combination of treatments such as mulch and fertilizer reduced plant mortality even further, but these treatments did not reduce infestation; it appears that their action enhanced the plants' ability to tolerate the infestation.

Figure 4. BSM resistance Nursery: plant mortality.

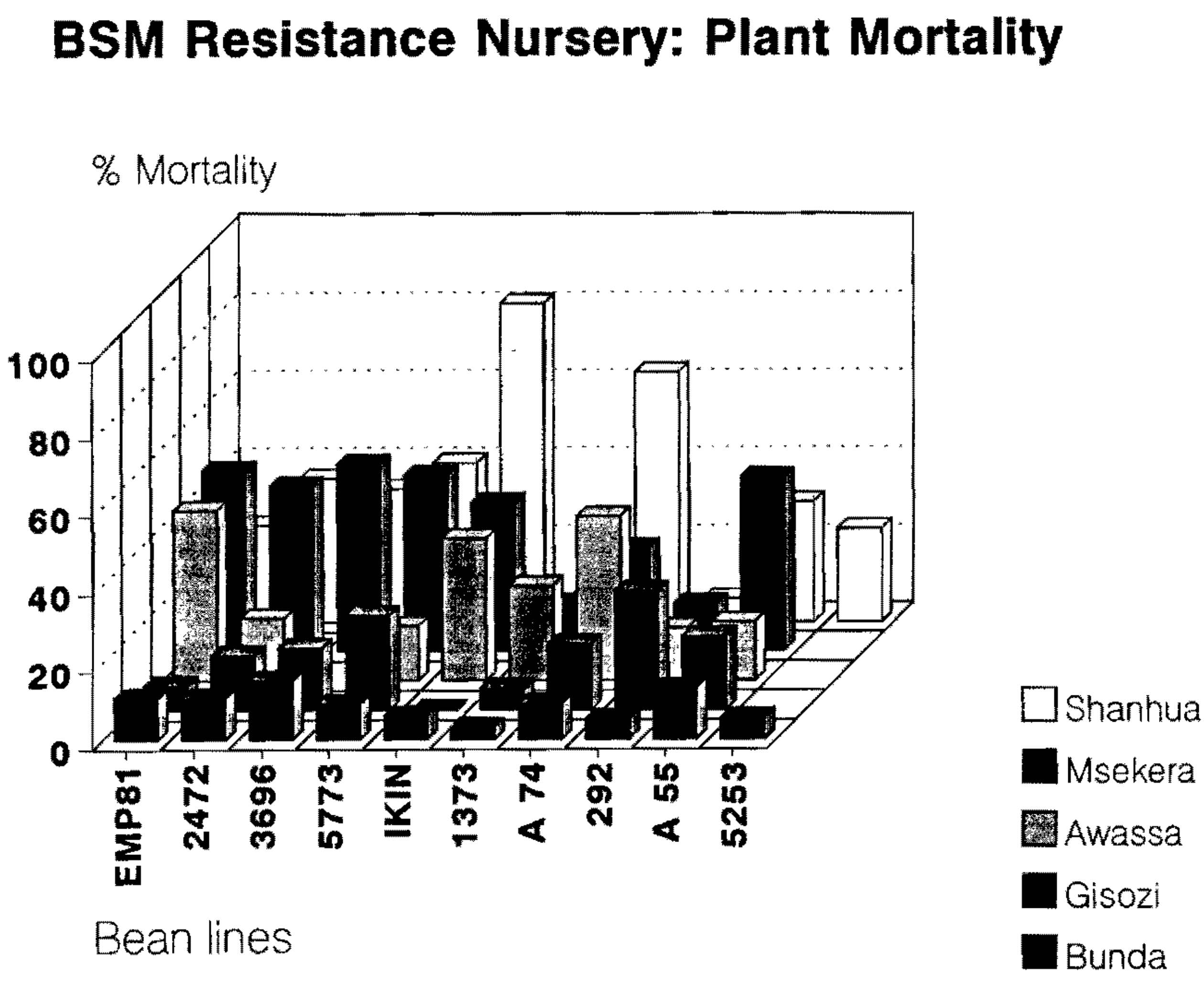


Table 4. Effect of certain cultural practices on BSM infestation and damage.

Treatment	Plant Std. at emerg.	% Infestation[1]	BSM inf. plant	BSM/dead plant	Total plant mort.
Control	91.7 a	100 a	4.5 a	6.7 a	25.5 a
Earthing-up	84.7 a	100 a	4.0 a	7.1 a	21.2 ab
Mulching	89.5 a	100 a	6.9 a	10.8 a	15.5 c
Fertilizer	90.0 a	100 a	4.4 a	11.9 a	21.2 ab
Seed dressing	89.5 a	100 a	4.0 a	1.0 b	3.0 d
Earthing-up + Mulching + Fertilizer	93.7 a	95 a	4.5 a	6.3 a	11.2 c
All combined	94.7 a	90 a	3.1 a	0.0 b	1.5 d
	NS	NS	NS	0.05	0.05

[1] At 6 WAE

Botanical pesticides

Certain plant extracts reputed to have insecticidal properties were evaluated alongside Endosulfan seed dressing for their performance against BSM. These were : (i) Neem seed extract (NSE) in aqueous solutions, (ii) NSE in alcohol; (iii) *Tephrosia* leaf juice, (iv) Maize leaf juice. These extracts were diluted to 10% and sprayed on to the plants (until dripping) at 3 - day intervals from emergence to flower-bud initiation. Plants were monitored for feeding/oviposition punctures (as an index of BSM adult activity), BSM infestation levels, plant mortality and yield.

Endosulfan seed dressing had no effect on adult BSM activity but had reduced infestation. NSE in alcohol, and *Tephrosia* juice reduced BSM adult activity indicating a deterrent effect from these substances. These reductions in BSM activity on test plots were reflected in infestation levels, plant mortality and yields also (Table 3). Maize juice and NSE in water had no effect on BSM. There were direct and significant correlations between BSM activity and infestation levels, plant mortality and yield.

DISCUSSION

Most bean farmers are resource poor and usually do not rely on purchased inputs in their crop management tactics. Such farmers are unlikely to adopt rigid packages but will select components that they can readily afford. Any integrated management strategy developed for use by such farmers should therefore, be flexible with options for step by step adoption of individual components. The key components considered in the present study were, host plant resistance, cultural control and botanical pesticides: all these are renewable within the farm environment and the farmer does not need extra financial resources to acquire them. He would, however, need education in their efficient use and management. Some of the components may need modifications to improve their efficiencies and considerations need to be given to other components in different farming systems for greater efficiency.

In this study there were significant correlations between oviposition/feeding punctures, infestation levels, plant loss and yield levels. These relationships may be evaluated further for use across varieties in predicting potential yield loss and to determine the economic threshold levels needed to justify the cost of inputs or operations as well as serving as a basis for scheduling measures aimed at reducing pest damage. Such indices as oviposition/feeding punctures would also help farmers recognize early signs of attack and make appropriate management decisions.

Other components that would fit in a management strategy include : (i) prophylactic treatment (e.g. seed dressing) - in areas where the pest is endemic. Such chemicals need to have some systemic qualities and be relatively persistent; (ii) remedial application of chemicals (such chemicals would essentially be systemic or at least penetrative in nature to reach the pest which spends its entire developmental stages within the plant tissue); (iii) sowing date adjustment in areas where periods of peak occurrence of damaging populations are well known to avoid plant exposure to these populations. Options such as biological control strategies involving the use of parasites and predators would have to be considered on area wide basis, as success would be influenced by the use of certain chemical pesticides.

The interaction between soil infertility, root diseases and BSM attack on the severity of damage expression suggest the need for a multidisciplinary approach to the development of IPM strategies for the BSM problem.

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DISCUSSION

Gethi : Disease may cause more mortality than BSM. Is there a possibility of confusion here ?

Ampofo : Mortality factors are generally partitioned into mortality due to BSM, root rot etc.

Kabungo : Has *O. spencerella* invaded Ethiopia from other areas since 1989 since it was not reported before this ?

Ampofo : It is unclear if *O. spencerella* is invading new areas or the confusion lies in species identification before 1989.

Nyirenda : It could be a reflection of improper identification but it must be borne in mind that species distribution can change.

Ampofo : It is possible that also that *O. spencerella* ecology is changing with time.

Agona : What is the effect of altitude on species distribution?

Ampofo : *O. spencerella* predominates at high altitude while *O. phaseoli* is found at lower altitude, but the relationship may be more of a temperature effect rather than altitude *per se*.

Mushi : In the crosses with BAT 1373 all the progenies died of black root indicating that I-gene was present. Have you noted similar in your evaluation ?

Ampofo : BAT 1373 has the I-gene.

Nderitu : Is mass rearing possible ?

Ampofo : Yes, but under our circumstances the problem is temperature control and oviposition on the artificial diet. Soybean cotyledons have however, been used successfully at AVRDC.

Mushi : Is Bean Stem Maggot important in Namibia ?

Ampofo : Namibia considers BSM important and is asking for the BSM.

Nyirenda : Do we have any publications on the BSM species determination?

Ampofo : Yes, there are various publications that deal with this. They include a paper by Dr Greathead in 1968, and a chapter in the Proceedings of the First Bean Entomologists' Working Group Meeting.

Nyirenda : I suggest we discuss the following:

1) training for identification of species.
2) what stage should the farmer be involved in identifying resistant material?
3) the possibility of producing suitable artificial diets.

SADC/CIAT SUB-PROJECT ON BREEDING FOR RESISTANCE TO BEAN STEM MAGGOT

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ABSTRACT

Research was conducted to study the inheritance of bean stem maggot resistance in bean (*Phaseolus vulgaris* L.) and the type of gene action involved in conferring resistance to BSM using the North Carolina Design III and a 9 x 9 partial diallel. The resulting progeny were evaluated under field populations of BSM. Data in the trials are still being collected, however, F_2 and F_3 generations behaved similarly for all traits measured indicating that resistance is heritable.

INTRODUCTION

In Africa, bean stem maggot (BSM) *Ophiomyia* spp. (Diptera: Agromyzidae) are the most important insect pests of the common bean (*Phaseolus vulgaris* L.). Yield losses of more than 50 percent have been attributed to bean stem maggot in Burundi (Autrique, 1985). In 1939 this pest was recorded in Tanzania where it bored through bean stems and caused total crop loss (Wallace, 1939). Wallace also noted e.g. to 100% infestation of plants in Njoro, Rongai, Sabukia, and Nairobi in Kenya. At the same time losses of 50% were recorded in snap beans in the Usambara mountains in Tanzania in January 1939, in some cases total loss was observed (Walker, 1960). Karel and Matee (1986) recorded seed yield losses of 33 percent in Morogoro, Tanzania.

All three *Ophiomyia* spp. viz: *O. phaseoli*, *O. spencerella* and *O. centrosematis* have been reported to occur in Africa. In Zambia, these species have been identified at the rates of 8, 88 and 4% respectively (1985 - 1986 Annual Report).

In Tanzania, *O. phaseoli* and *O. spencerella* have be reported to occur but the latter appears to predominate (Slumpa and Ampofo, 1990). Lays and Autrique (1987) reported that all three species occur in Burundi. Recently it has been reported that all three species occur in Tanzania (Slumpa personal communication).

Several studies have been conducted on the resistance of beans and other legumes to *O. phaseoli*. In Melkassa, Ethiopia, of the 177 bean lines evaluated for their resistance to the BSM, only five lines showed no symptoms of attack nor pupal populations (Abate, 1983). In 1977 and 1978 at the Asian Vegetable Research and Development Center (AVRDC) in Taiwan, 370 bean accessions from CIAT were screened for resistance to BSM. Based on the number of insects/plant and the percentage of damaged plants, 48 accessions showed low to moderate levels of resistance. When these accessions where evaluated in an identical trial for the second time, only eight showed moderate levels of resistance. To confirm their resistance, seven out of the eight accessions, together with two susceptible checks, were planted in a replicated trial in autumn 1979. Two accessions, G 05478 (*P. vulgaris*) and G 35023 (*P. coccineus*), showed a significantly lower attack than the susceptible checks (CIAT, 1983). Screening work done in Morogoro, Tanzania in 1983 to 1985 showed low resistance to *O. phaseoli* in the following lines: A 489, A 429, BAT 1570, TMO 118, BAT 1500, A 476 and TMO 101 (Karel *et al.*, 1983, 1984, 1985). However, no work is reported todate on the confirmation on resistance in these lines. In Chipata, Zambia, TMO 110, TMO 78, TMO 101 and G 5478 had high grain yield which was attributed to resistance to BSM found in those lines.

Literature above indicated that the initial stage of breeding for resistance has commenced with success in identifying some lines with resistance. While the screening work is in process, lines proven to have some resistance should be utilized to transfer the resistance genes into adapted varieties and "cultivars". Before such process is effected, the inheritance of resistance need to be established which will then determine the kind of breeding procedure to follow in developing BSM resistant varieties. Therefore, the objectives of this sub-project are:

1. Study inheritance of resistance to BSM *Ophiomyia* spp. and the type of gene action conferring resistance.
2. Develop an appropriate breeding methodology for developing BSM resistant varieties.
3. Continue screening for new sources of resistance in the local landraces and introductions.

PROGRESS AND ACHIEVEMENTS

Experiment 1. To Study the Inheritance of Resistance to Bean Stem Maggot

MATERIALS AND METHODS

In February 1991 lines that were reconfirmed to have high levels of resistance to bean stem maggot were crossed to susceptible but adapted cultivars. The resistant lines were ZPV 292 and Ikinimba, and the susceptible cultivars were Lyamungu 85, Canadian Wonder, and Dore de Kirundo.

The crosses were advanced to F_2 and later to F_3 with remnant seed of F_2 kept for field evaluation. Both the F_2 and F_3 populations together with their parents were sown at Selian Agricultural Research Institute in 1992 after the Masika rains; time when the BSM population was very high. The crosses were arranged in a randomized complete block design in three replications and two checks of Lyamungu 85 treated with Fernasan D and untreated were sown after every seven plots. The plot size was two rows, three meters long spaced 50 cm. apart. The intra row spacing was 20 cm with two seeds per hill. Plots were kept free from weeds and irrigation was done whenever necessary.

Sampling of dead plants was done twice every week until flowering. The dead plants were counted brought to the laboratory, dissected and number of black and brown pupae per plant determined. From flowering the trial was sprayed whenever necessary to protect it from flower beetles and pod sucking insects. The data was analyzed using General Linea Model Procedure of SAS.

Table 1. Crosses parents and checks and their cumulative mortality.

Entry	Pedigree	Description	Cumulative mortality mean
1.	ZPv 292 x Lyamungu 85	BSM 01 - F_2	7.333
2.	ZPv 292 x Lyamungu 85	BSM 02 - F_2	9.333
3.	ZPv 292 x Lyamungu 85	BSM 03 - F_2	7.000
4.	ZPv 292 x Lyamungu 85	BSM 04 - F_2	3.333
5.	ZPv 292 x Lyamungu 85	BSM 05 - F_2	10.333
6.	ZPv 292 x Lyamungu 85	BSM 06 - F_2	12.000
7.	ZPv 292 x Lyamungu 85	BSM 07 - F_2	10.000
8.	ZPv 292 x Lyamungu 85	BSM 08 - F_2	8.667
9.	ZPv 292 x Lyamungu 85	BSM 01 - F_2	6.000
10.	ZPv 292 x Lyamungu 85	BSM 10 - F_2	8.667
11.	Ikinimba x Dore de Kirundo	BSM 16 - F_2	5.667
12.	ZPv 292 x Canadian Wonder	BSM 25 - F_2	10.667
13.	ZPv 292 x Canadian Wonder	BSM 26 - F_2	10.000
14.	ZPv 292 x Canadian Wonder	BSM 27 - F_2	4.667
15.	ZPv 292 x Canadian Wonder	BSM 28 - F_2	11.000
16.	ZPv 292 x Canadian Wonder	BSM 29 - F_2	7.333
17.	ZPv 292 x Canadian Wonder	BSM 30 - F_2	6.000
18.	ZPv 292 x Canadian Wonder	BSM 31 - F_2	7.667
19.	Ikinimba x Lyamungu 85	BSM 34 - F_2	8.000
20.	Ikinimba x Lyamungu 85	BSM 37 - F_2	3.667
21.	Ikibimba x Lyamungu 85	BSM 38 - F_2	4.000
22.	Ikinimba x Lyamungu 85	BSM 39 - F_2	9.000
23.	Ikinimba x Lyamungu 85	BSM 41 - F_2	2.333
24.	Ikinimba x Lyamungu 85	BSM 43 - F_2	8.333
25.	ZPv 292 x Dore de Kirundo	BSM 46 - F_2	9.333
26.	ZPv 292 x Dore de Kirundo	BSM 47 - F_3	4.333
27.	ZPv 292 x Canadian Wonder	BSM 48 - F_3	10.000
28.	ZPv 292 x Canadian Wonder	BSM 49 - F_3	3.333
29.	ZPv 292 x Canadian Wonder	BSM 50 - F_3	8.667
30.	ZPv 292 x Canadian Wonder	BSM 51 - F_3	9.000
31.	ZPv 292 x Lyamungu 85	BSM 53 - F_3	9.000
32.	ZPv 292 x Lyamungu 85	BSM 54 - F_3	5.000
33.	ZPv 292 x Lyamungu 85	BSM 55 - F_3	7.667
34.	ZPv 292 x Lyamungu 85	BSM 56 - F_3	7.333

Table 1. Contd.

Entry	Pedigree	Description	Cumulative mortality mean
35.	ZPv 292 x Lyamungu 85	BSM 57 - F_3	5.000
36.	ZPv 292 x Dore de Kirundo	BSM 34 - F_3	6.000
37.	Ikinimba x Canadian Wonder	BSM 37 - F_3	11.333
38.	Ikibimba x Canadian Wonder	BSM 38 - F_3	9.667
39.	Ikinimba x Canadian Wonder	BSM 39 - F_3	7.667
40.	Ikinimba x Lyamungu 85	BSM 41 - F_3	4.667
41.	Ikinimba x Lyamungu 85	BSM 43 - F_3	5.000
42.	Ikinimba x Dore de Kirundo	BSM 46 - F_2	6.000
43.	ZPv 292	Parent	8.667
44.	Sinon	Check	6.333
45.	ZAA 12	Check	4.000
46.	Lyamungu 85	Parent	18.000
47.	Canadian Wonder	Parent	6.333
48.	BSM 52	Check	5.667
49.	Dore de Kirundo	Parent	13.333
50.	Ikinimba	Parent	3.667

RESULTS AND DISCUSSION

Field performance of crosses and their parents to bean stem maggot is presented in Table 2. There were significant differences among crosses in both sampling periods for percent cumulative mortality, mortality caused by bean stem maggot, and number of black pupae per plant. Number of brown pupae per plant was not significant in both sampling periods and the number was lower than the black ones indicating that *O. spencerella* was the predominant species. The parental lines performed similarly in the two sampling periods except for the mortality caused by BSM which differed significantly (P=0.05) among parents in the second sampling period.

The F_2 and F_3 crosses behaved similarly in both sampling periods for all traits measured (Table 3). This similarity between F_2 and F_3 crosses suggest that resistance to BSM is heritable.

Tables 4 and 5 present data on the performance of resistant and susceptible parents respectively. There were no significant differences among them for the variables measured. The resistant parents had generally lower percent total mortality, mortality by BSM, abundance of black pupae per plant and brown pupae per plant. These demonstrate the high level of resistance found in the resistant parents. However, Canadian wonder behaved differently from what it was expected. It demonstrated similar levels of resistance to ZPv 292 except for the number of black pupae per plant Table 5.

Table 2. Performance of crosses and parents to Bean Stem Maggot.

Variable	1st Sampling Period		2nd Sampling Period	
	Crosses	Parents	Crosses	Parents
Parent cumulative mortality	0.096**	0.183 NS	0.247**	0.350 NS
Mortality by BSM	0.087**	0.174 NS	0.234**	0.327*
Black pupae per plant	5.699**	6.853 NS	10.404**	0.346 NS
Brown pupae per plant	0.081 NS	0.096 NS	0.239 NS	0.346 NS

NS = not significant; * and ** denote significance at probability levels of 5 and 1% respectively.

Table 3: Performance of F_2 and F_3 crosses to BSM.

Variable	1st Sampling Period		2nd Sampling Period	
	F_2	F_3	F_2	F_3
% Cumulative mortality	0.082 NS	0.097 NS	0.228 NS	0.263 NS
Mortality by BSM	0.076 NS	0.084 NS	0.218 NS	0.248 NS
Black pupae per plant	6.615 NS	6.081 NS	10.741 NS	12.974 NS
Brown pupae per plant	0.084 NS	0.110 NS	0.196 NS	0.248 NS

Table 4. Performance of resistant parental lines to Bean Stem Maggot

Variable	1st Sampling Period		2nd Sampling Period	
	ZPv 292	Ikinimba	ZPv 292	Ikinimba
% Cumulative mortality	4.66 NS	2.0 NS	8.67 NS	3.67 NS
Mortality by BSM	4.33 NS	1.33 NS	6.67 NS	3.21 NS
Black pupae per plant	8.54 NS	3.08 NS	5.46 NS	14.19 NS
Brown pupae per plant	0.33 NS	0.0 NS	0.19 NS	0.58 NS

The field performance for crosses with Ikinimba and ZPv 292, indicate that generally Ikinimba has slightly more resistance transferred to the crosses for the number of black pupae per plant than ZPv 292 (Tables 6 and 7). Data from these tables also indicate that the difference among crosses for each variable measured is very small suggesting that there is more additive gene action and that dominance gene action is very small.

Table 5. Performance of susceptible parental lines to Bean Stem Maggot.

Variable	1st Sampling Period			2nd Sampling Period		
	Lya 85	CW	Dore	Lya 85	CW	Dore
% Cumulative mortality	11.67	2.33	7.33	18.0	6.3	13.3
Mortality by BSM	11.67	2.0	7.33	19.3	5.7	12.7
Black pupae per plant	7.8	7.5	7.26	19.8	10.0	18.8
Brown pupae per plant	0.10	0.0	0.27	0.5	0.3	0.4

Lya 85 = Lyamungu 85; CW = Canadian Wonder; Dore = Dore de Kirundo

Table 6. Performance of crosses with Ikinimba to Bean Stem Maggot.

Variable	1st Sampling Period			2nd Sampling Period			Mean
	Ikin x Dore	Ikin x Lya	Ikin x CW	Ikin x Dore	Ikin x Lya	Ikin x CW	
Mortality by BSM	0.084	0.09	0.10	0.220	0.26	0.23	1.16
Black pupae per plant	6.056	5.82	9.47	8.115	11.96	9.39	8.5
Brown pupae per plant	0.0	0.07	0.0	0.208	0.29	0.13	0.1

Ikin x Dore = Ikinimba x Dore de Kirundo; Ikin x Lya = Ikinimba x Lyamungu;
Ikin x CW = Ikinimba x Canadian Wonder.

Table 7. Performance of crosses with ZPv 292 to Bean Stem Maggot.

Variable	1st Sampling Period			2nd Sampling Period			Mean
	ZPv 292 x Dore	ZPv 292 x Lya	ZPv 292 x CW	ZPv 292 x Dore	ZPv 292 x Lya	ZPv 292 x CW	
Mortality by BSM	0.109	0.082	0.085	0.205	0.229	0.250	0.16
Black pupae per plant	7.453	6.155	6.794	11.338	10.677	13.401	9.30
Brown pupae per plant	0.056	0.108	0.131	0.153	0.138	0.171	0.15

ZPv 292 x Dore = ZPv 292 x Dore de Kirundo; ZPv 292 x Lya = ZPv 292 x Lyamungu;
ZPv 292 x CW = ZPv 292 x Canadian Wonder.

CONCLUSION

The resistant parents showed higher levels of resistance to BSM and were similar in performance indicating that they can both be used to develop resistant cultivars. The F_2 and F_3 crosses reacted similarly for all traits measured indicating that resistance to BSM is heritable. However, this is only tentative conclusion pending verifications when heritability estimates are determined.

Experiment 2: To study type of gene action conferring resistance to BSM

MATERIALS AND METHODS

The North Carolina Design III has bean employed in this study. The sources of resistance were crossed to susceptible lines, and F_1's advanced to F_2 generation. The materials for estimation of genetic parameters were produced by crossing randomly selected F_2 individuals (used as males) to each of the original parents (used as females). Due to the few number of parents that were available by that time and used in this study, a 9 x 9 partial diallel has been made using parents identified as having high levels of resistance. The crosses are being advanced to F_2 for verification if they are crosses and increase seed. The true crosses will be screened against bean stem maggot when the population is high later this year.

RESULTS

The crosses made for North Carolina Design III are presented in Table 1 and those for 9 x 9 partial diallel are presented in Table 2. Seed from all the first set of crosses was planted at a site in Lyamungu under irrigation in November 1993 time when BSM population was high. Due to the high incidence of root rot that prevailed no reliable data on bean stem maggot could be collected. Hence this study will rely on data from diallel crosses only.

Table 1. BC_1 F_2 Bean Stem Maggot Crosses.

	♀		♂		
1.	ZPv 292	x	(ZPv 292	x	Lyamungu 85)
2.	ZPv 292	x	(ZPv 292	x	Canadian Wonder)
3.	ZPv 292	x	(ZPv 292	x	Dore de Kirundo)
4.	Ikinimba	x	(Ikinimba	x	Lyamungu 85)
5.	Ikinimba	x	(Ikinimba	x	Canadian Wonder)

Table 2. 9 x 9 Partial Diallel - Crosses

No.	♀		♂		♀		♂
1.	Ikinimba	x	ZPv 292	19.	G 3844	x	G 2072
2.	Ikinimba	x	G 5773	20.	EMP 81	x	BAT 76
3.	Ikinimba	x	G 3844	21.	EMP 81	x	G 247
4.	Ikinimba	x	EMP 81	22.	EMP 81	x	G 2005
5.	Ikinimba	x	BAT 76	23.	EMP 81	x	G 2072
6.	Ikinimba	x	G 2472	24.	BAT 76	x	G 2472
7.	Ikinimba	x	G 2005	25.	BAT 76	x	G 2005
8.	Ikinimba	x	G 2072	26.	BAT 76	x	G 2072
9.	G 5773	x	G 3884	27.	G 2472	x	G 2005
10.	G 5773	x	EMP 81	28.	G 2472	x	G 2072
11.	G 5773	x	BAT 76	29.	G 2005	x	G 2072
12.	G 5773	x	G 2472	30.	ZPv 292	x	G 5773
13.	G 5773	x	G 2005	31.	ZPv 292	x	G 3844
14.	G 5773	x	G 2072	32.	ZPv 292	x	EMP 81
15.	G 3844	x	EMP 81	33.	ZPv 292	x	BAT 76
16.	G 3844	x	BAT 76	34.	ZPv 292	x	G 2472
17.	G 3844	x	G 2472	35.	ZPv 292	x	G 2005
18.	B 3844	x	G 2005	36.	ZPv 292	x	G 2072

Part II : Development of resistant cultivars with desirable seed colour

MATERIALS AND METHODS

Crosses between the resistant cultivars and adapted cultivars were advanced to F_5 by single hill descent. These were separated into different colours per cross and evaluated for yield at Lambo and against BSM at Lyamungu, Moshi.

RESULTS

The trial at Lambo has been harvested but seed has not been processed for yield determination. However, due to the drought that this site experienced, yield will be lower than expected. The trial at Lyamungu was evaluated for BSM but due to the lower population that prevailed, the trial is being repeated again in this coming short rains (October).

Part III: Development of apropriate breeding procedure

MATERIALS AND METHODS

Crosses made between resistant and susceptible cultivars were advanced to F_3 by single plant descent. F_3 crosses were evaluated at Selian as detailed in Experiment 1 above. Single plant selections were made and evaluated in progeny rows at Lyamungu under irrigation in early 1993. Also resistant plants were selected seed combined per family and evaluated at Lyamungu as above. This means two breeding procedures are being evaluated viz;

1. Combination of single hill descent and pedigree.
2. Recurrent selection.

RESULTS

Due to the low BSM population that prevailed in the previous evaluation, the trials are being repeated again in this October.

Future work

1. Composition of BSM regional nursery: The F_6 lines will be sent out to interested National Programmes for further evaluation.
2. Completion of the trials mentioned above, data analysis and report writing.
3. Incorporate resistant to adapted lines from other National Programmes, advance them to F_3 and send back to respective programmes for evaluation and selection.
4. Continue screening for new sources of resistance.

DISCUSSION

Giga	:	Are the species and BSM of equal importance in the long and short rainy seasons?
Mushi	:	There are 3 species present, *O. Spencerella* is the most important but changes in dominance have been observed.
Chisahayo	:	Why didn't you calculate heredity before choosing the breeding methods? How will you screen for BSM resistance, colour and yield?
Mushi	:	I haven't chosen a breeding programme but I am comparing two breeding procedures because of lack of time. After heredity estimates are know the appropriate programme will be chosen and screening made for BSM and yield at hot spots with and without protection.
Gethi	:	What other physical characteristics did you use for your selection for resistance?
Mushi	:	Per cent plant mortality and infestation levels. Mortality due to root rot is also distinguished.
Youngquist	:	There are complications with single pod descent. Maybe single seed descent is better ?

PROGRESS IN BEAN BRUCHID RESEARCH IN SADC

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ABSTRACT

The results and progress of a sub-regional project jointly funded by SADC/CIAT and Rockefeller Foundation are summarized in this paper. Several experiments have been conducted to test traditional grain protection methods in the laboratory and in simulated storage conditions. Detailed surveys of small farmers bean storage systems in Zimbabwe were conducted to obtain information on bean production and post harvest practices and to identify constraints faced by farmers to efficient bean storage. Information on the distribution of bean bruchids in Africa is presented. Our studies also evaluated the susceptibility of bruchid resistant germplasm developed at CIAT, the incidence of bruchids in the mature bean crop and the extent of infestation in beans stored in the pod. A series of experiments were performed to study the competitive interactions between the two species of bruchids at different temperatures. The outcome of competition was dependent on the temperature.

INTRODUCTION

A wide range of insect pests attack and cause significant damage to the bean crop in the field. In storage two bruchid species are of importance wherever beans are grown and stored in Africa. However, because of limited resources entomologists have focused the research on a few key species that constrain bean production.

At the First Pan-African Working Group Meeting on Bean Entomology in August 1989 three key pests, namely beanfly (*Ophiomyia* species); bruchids (*Zabrotes subfasciatus* and *Acanthoscelides obtectus*) and aphids as vectors of BCMV were identified as consistently constraining bean productivity across regions in Africa. A collaborative research proposal linking the University of Zimbabwe, Sokoine University and the Selian Research Centre (Tanzania) was presented at the 2nd SADC/CIAT Regional Bean Research Workshop held in Morogoro, Tanzania from 17 - 22 September 1990. The objectives of the research proposal were to obtain detailed information on small farmers' bean storage systems, losses in storage, bruchid species composition and distribution and economically viable control methods. This regional collaborative research sub-project has now been running for about 2.5 years with good progress being made towards the objectives. Further information on bean storage systems, conservation practices, constraints to efficient storage and bruchid species distribution was obtained during a monitoring/evaluation tour of major bean production areas in Uganda, Tanzania and Zimbabwe.

The following were noted at the 2nd SADC/CIAT Bean Research Workshop regarding bruchid research in the "eighties":

- information on losses in storage was scanty and loss assessment methods lacked standardization to enable comparisons between studies.
- the extent of adoption of research findings and recommendations of bean conservation measures is not known but likely to be low.
- host plant resistance to *Zabrotes* has been identified and incorporated into breeding lines at CIAT.

At the same meeting the following strategies were recommended for the "nineties":

- studies of species composition, adaptation and distribution.
- loss assessment studies with emphasis on improving methodologies for accurate assessments.
- studies of control methods including the use of plant products with due consideration of farmer acceptability.
- studies on pod wall characteristics for resistance to field infestations by *Acanthoscelides.*
- evaluation of *Zabrotes* resistant lines from CIAT against local strains and incorporation of resistance in local varieties.

OBJECTIVES OF THE SUB-PROJECT

1. To identify and evaluate the constraints to efficient bean storage faced by small scale farmers in SADCC.
2. To assess crop losses incurred by small farmers through the use of traditional bean storage.
3. To assess levels of infestation and species composition and distribution.
4. To investigate interspecies interactions (competition) and competitive abilities of *Zabrotes* and *Acanthoscelides* at different temperatures.
5. To study the bionomics of geographically distinct strains of the two bruchid species from different agro-ecological zones.
6. To screen *Phaseolus* germplasm from CIAT, national and regional breeding programmes for resistance to local strains of bruchid species.
7. To develop and evaluate simple and cost effective bean storage technologies for use by small scale farmers.

PROGRESS TO DATE

A number of experiments have been conducted to date and several have been planned for the coming season towards achieving the above mentioned objectives. This paper briefly reports on the experiments conducted and highlights some of the results. The following studies have been completed or are currently in progress.

(i) survey of bean production and post production practices in Zimbabwe and Tanzania.
(ii) survey of bean bruchid species composition and distribution in Africa.
(iii) evaluation of selected traditional grain protectants in laboratory and simulated trials.
(iv) screening "RAZ" lines for bruchid resistance.
(v) agronomic evaluation of "RAZ" lines.
(vi) bruchid species incidence and populations in the field.
(vii) infestations of pods and threshed grain (both artificial and natural) in relation to time in storage.
(viii) solar disinfestation of infested beans.
(ix) evaluation of absorptive dusts (Dryacide) as a grain protectant.
(x) interactions between *Zabrotes* and *Acanthoscelides* at different temperatures.

SURVEYS OF BEAN PRODUCTION AND POSTHARVEST PRACTICES

A questionnaire survey was conducted in 14 districts in four Provinces (Mashonaland east, Mashonaland central, Mashonaland west and Masvingo) of Zimbabwe to obtain information on bean production and postharvest practices. A detailed paper on the findings of the survey was presented at 3rd SADC/CIAT Regional Workshop held in Swaziland from 5 - 7 October 1992. A similar survey is currently underway in Tanzania.

SPECIES DISTRIBUTION IN AFRICA

In order to obtain information on the distribution of *Zabrotes* and *Acanthoscelides* in Africa a postal survey was conducted in which information on species of bruchids attacking beans, altitude and temperature of areas where the bruchids occur were requested from entomologists in various countries. Responses received were summarized and presented at the Swaziland workshop. Further information on species distribution in Uganda, Tanzania and Zimbabwe was obtained during a recent monitoring tour of those countries. Collaborators in Tanzania have also conducted surveys in the Morogoro region. In addition all records of the two species at the International Institute of Entomology and the British Natural History Museum (London) were examined. Literature suggests that *Acanthoscelides* is restricted to the cooler highlands (higher altitudes) while *Zabrotes* is confined to warmer (low altitude) areas. The two species appear to differ in ecological adaptations and have defined distributions dependent largely on temperature and altitude in Latin America. However, our observations in Africa indicate no clear distribution patterns, particularly in Tanzania and Uganda where surveys were more extensive. In Uganda, for example, *Zabrotes* is not confined to any particular region. It was more predominant in urban stores and tends to appear at the time of the year when temperatures are high. In Tanzania, *Acanthoscelides* occurs in areas ranging in altitude from 600 - 1500 m with the notable exception of Babati (altitude 1500 m) where only *Zabrotes* were recorded. In the Morogoro region (altitude 350 - 1800 m) personal observations revealed the presence of *Acanthoscelides* only, while Nchimbi and co-workers' surveys reported the occurrence of both species. Their observations in Arusha, Morogoro and Dodoma districts at altitudes ranging from 350 - 1800 m showed *Zabrotes* to predominate irrespective of altitude during March to August. About 80% of the bruchids in the population complex consisted of *Zabrotes*. In Ethiopia Negasi's surveys (pers. comm.) showed that between 1550 - 1900 m *Acanthoscelides* was present while in the lowlands of altitude of 1500 m *Zabrotes* was the only species present. At mid altitude both species were observed but *Acanthoscelides* was more common. In Burundi (Nahimana, pers. comm.) *Zabrotes* is found throughout the range of altitude 800 - 1400 m. *Acanthoscelides* occurs at 1600 m and above, but its limits are unclear. The situation becomes very unclear because the terms highlands/lowlands/mid altitude are relative depending on the country. For example, what Ethiopians regard as lowlands are obviously classified as highlands in other countries.

The range of altitudes in which the two bruchid species occur suggests that both species have a wide range of adaptation in Africa. As a result of our studies many questions arise on the distribution, abundance and timing of infestations in Africa. These include:

Why is *Zabrotes* more predominant in some areas of high altitude and why do localized pockets of the species occur ?

What are the limiting factor(s) determining the distribution of the species ?

Why do results of different surveys differ so significantly ?

Is the presence or absence of a species in any particular area dependent on the time of the year surveys are conducted ?

What are the upper and lower temperature limits that the African strains can tolerate ?

Are there strain differences between the species from different agro-ecological zones ?

To what extent do interactions between the two species determine abundance and spread? The distribution and abundance of bruchid species in Africa is not clearly defined with the situation being much more complex than previously thought.

EVALUATION OF TRADITIONAL GRAIN PROTECTANTS

Mixing powdery substances (whether inert or insecticidal) with grain, in order to protect it against insect infestation, is a traditionally based, time-honoured and universal practice that is still used in Africa. There is a variety of different materials which farmers add to their produce namely, fine sand, wood ashes and plant materials having insecticidal properties. One of the major setbacks to the adoption of such treatments in insect control is the bulky nature of the amounts needed to give effective grain protection.

Our recent surveys in Tanzania, Uganda and Zimbabwe showed that, farmers used various admixtures for seed and grain for home consumption but would not extend the use to the marketable surplus because of the extra cleaning required prior to sale. The efficacy of the additives, however, has been reported by farmers to vary greatly. Experiments were therefore designed to evaluate the efficacy of selected materials commonly used in admixes in laboratory and simulated on-farm storage in clay pots.

Laboratory trials

In this trial admixing grain with wood ash, sand, "rapoko husks", sunhemp seeds (*Crotalaria*) and neem leaf powder at various rates was evaluated against the two species of bruchids at 26.5°C and 55 - 60% relative humidity. The materials were tested at 0, 0.25, 0.5 and 1.0 to 1.0% (v/v) of beans.

Results and Discussion

The results (Tables 1 and 2) show that the additives applied at the higher rates were effective in reducing insect multiplication and grain damage. The ash treatment was the most effective at all rates. For the other substances, an application rate of at least 1:1 (v/v) was required to reduce insect numbers and damage significantly.

Simulated storage trials in clay pots

The effectiveness of ash, sand, vegetable oils and "rapoko husks" admixed with beans and stored at ambient conditions in clay pots was tested. The amounts of the substances added corresponded to an equivalent volume rate of 0.25:1 (substance: beans) and the oil was applied at 7.5 ml/kg beans. Each clay pot containing 2 kg of treated beans was infested with 400 freshly emerged insects. The experiment was replicated three times and performed separately for each of the two species. The number of bruchids developed and percentage damage were measured for each treatment.

Table 1. The effect of admixing different substances with beans at various rates on damage and development of *Z. subfasciatus*.

Rate (v/v)	Substance	Mean number of F_1 emerge	Mean % damage
0:1	Control	148.4	84.5
0.25:1	Rapoko	141.0	45.5
	Neem	156.6	49.3
	Ash	102.4	35.5
	Sunhemp	153.6	73.5
	Sand	128.0	49.6
0.5:1	Rapoko	124.0	22.6
	Neem	99.6	15.0
	Ash	15.4	5.2
	Sunhemp	136.8	61.8
	Sand	50.4	17.8
1:1	Rapoko	81.0	10.3
	Neem	27.0	2.5
	Ash	7.8	1.8
	Sunhemp	110.2	29.1
	Sand	48.8	6.1
SED between treatment means		0.94	0.06

Table 2. The effect of admixing different substances with beans at various rates on damage and development of *A. obtectus*.

Rate (v/v)	Substance	Mean number of F_1 emerge	Mean % damage
0:1	Control	120.6	64.6
0.25:1	Ash	17.2	9.5
	Sand	101.0	47.3
	Rapoko	120.8	53.2
	Neem	135.8	56.3
	Sunhemp	77.4	47.6
0.5:1	Ash	0	0.1
	Sand	86.4	31.5
	Rapoko	24.3	15.8
	Neem	81.1	30.1
	Sunhemp	82.2	55.5
1:1	Ash	3.2	0.1
	Sand	18.2	7.0
	Rapoko	7.4	7.5
	Neem	7.2	5.1
	Sunhemp	91.2	51.5
SED between treatment means		1.19	0.06

Results and Discussion

Table 3 summarizes the results of adult emergence and damage on stored beans. This trial demonstrates that the admixtures protect the grain but their effects varied significantly. Oil, followed by wood ash were the most effective treatments in controlling both bruchid species.

Table 3. Effect of admixing different substances on damage and in development of (a) *Z. subfasciatus* and (b) *A. obtectus* in clay pots trials.

Treatment	Application rate per kg beans	Number F_1 emergents	%Damage
(a) *Z. subfasciatus*			
Control	-	3167.0	66.4
Oil	7.5 ml	0	0
Ash	220.5 g	761.3	6.1
Sand	500.2 g	2824.3	28.4
Rapoko	35.3 g	2852.3	37.7
SED		2.28	0.06
(b) *A. obtectus*			
Control	-	3662.6	42.8
Oil	7.5 ml	0	0
Ash	220.5 g	33.0	0.8
Sand	500.2 g	2929.7	27.9
Rapoko	35.3 g	2588.7	25.4
SED		8.87	0.07

SED = Standard error of a difference

EVALUATION OF VEGETABLE AND NEEM OILS

Application of edible or neem oils to protect food legumes (e.g. cowpeas, beans, green grams, chickpeas) is a common practice in West Africa, South America and Asia. However, our surveys show that this conservation technique, though very effective, is rarely practiced in the SADCC region. For the resource poor farmers who store small quantities of beans for home consumption admixing oils at 5 ml/kg of beans is a practical and cost effective option.

In order to demonstrate the advantages and efficacy of oil treatments, two locally available edible oils (sunflower and a blend of cotton seed-soya bean oil) and a commercial formulation of neem oil at different rates were compared with an insecticide, pirimiphosmethyl. The results of this experiment will be presented at this meeting by a co-worker (P.Chinwada).

SCREENING "RAZ" LINES FOR RESISTANCE

Following the identification of resistance to *Zabrotes* in wild bean accessions and the identification of arcelin, a novel seed protein, as a factor responsible for resistance a large scale breeding programme was initiated at CIAT. A large number of lines (RAZ resistance to *Zabrotes*) were developed and tested for yield and resistance against local strains of *Zabrotes* in South America and Africa (Uganda). As there is great variability in biological characteristics between strains in bruchid species it is useful that screening of this germplasm also be performed using African strains in addition to those at CIAT.

Fifty-three RAZ lines were acquired from CIAT and multiplied over 2 seasons to obtain enough seed for resistance tests against *Zabrotes* and *Acanthoscelides*. The number of eggs laid, number of progeny emerged, percentage emergence, development periods and the damage caused were measured for both species. Agronomic characteristics of the lines were also recorded.

Results and Discussion

Zabrotes

The RAZ lines did not deter oviposition by *Zabrotes*. The mean number of eggs laid on the beans varied from 69.4 (RAZ 7) to 197.8 (RAZ 18-1). Although the majority of the eggs hatched and the larvae penetrated the seed coat, as indicated by the white coloration of egg shells left behind, very few larvae developed successfully into adults (Table 4). The mean number of adults that emerged from the RAZ lines varied from 0 in RAZ 25 - 1 to 22.0 in RAZ 20 - 2. From the susceptible check variety (Natal Sugar) 148.8 adults emerged with a survival rate of 84.1%. The percentage emergence (survival) of adults from eggs laid ranged from 0 to 13.4 in the RAZ lines. The development periods of those adults that emerged from the RAZ lines were significantly longer (39.6 - 69.0 days) than those from the susceptible check (31.4 days). Damage levels were significantly greater in the susceptible check compared to the RAZ materials. Although a few adults had emerged from most of the RAZ lines they were small and "unfit". These results show that resistance was expressed in the following ways:

- (i) prolonged development period
- (ii) mortality of larvae within the seed (antibiosis)
- (iii) mortality in the pupal stage
- (iv) failure of adults to emerge (although "windows" appeared)
- (v) reduction in adult weight and fitness.

Table 4. Effect of "RAZ" lines on the biology of *Z. subfasciatus*.

Breeding line	No. of eggs laid	No. of F1 adults emerged	% F1 emergence	Days to adult emergence	No. of seeds damaged
RAZ 4-2	139.2	1.0	0.79	54.0	1.0
5	71.6	3.6	5.78	52.6	2.8
7	69.4	1.0	1.33	48.0	1.0
8	88.6	2.0	2.32	55.4	1.8
9	118.6	12.2	7.64	45.4	7.0

Table 4. Contd.

Breeding line	No. of eggs laid	No. of F1 adults emerged	% F1 emergence	Days to adult emergence	No. of seeds damaged
9-1	175.2	15.4	8.48	45.4	11.0
9-2	168.4	12.2	8.08	41.2	9.0
9-4	73.6	5.4	6.83	47.8	4.2
10	195.8	8.2	4.18	48.6	6.0
11	168.8	0.6	0.35	50.3	0.6
11-1	131.4	0.2	0.14	69.0	0.2
12	193.0	7.6	3.86	47.8	0.6
12-2	99.0	13.4	12.09	49.6	7.6
12-4	164.0	5.2	3.14	56.8	3.0
13	139.8	7.6	5.09	48.2	5.4
13-1	171.4	5.2	3.05	47.2	4.6
13-2	172.6	4.4	2.64	47.8	3.6
13-3	169.2	4.0	2.48	50.8	3.2
13-4	146.2	0.2	0.14	69.0	2.0
13-5	181.0	0.2	0.10	47.0	0.2
13-6	144.2	4.0	2.76	50.2	3.4
14	175.0	7.6	4.41	44.4	7.6
14-1	187.0	8.8	5.04	48.4	7.6
15	175.0	11.2	6.34	43.8	9.6
16	140.6	3.2	2.21	52.0	2.6
17	170.2	2.0	1.19	51.2	2.2
17-1	170.8	3.6	2.06	53.6	3.8
17-2	178.0	5.0	2.75	48.6	3.8
17-3	78.6	3.6	4.84	52.6	3.6
17-5	165.0	3.4	2.03	39.6	2.6
17-6	130.6	1.0	0.74	59.5	0.8
17-7	187.0	14.0	7.59	45.8	9.0
18	175.4	4.0	2.17	52.8	3.4
18-1	197.8	1.6	0.73	51.3	1.6
19	169.6	2.4	1.37	45.8	2.0
20-1	158.2	0.4	0.28	58.8	0.4
20-2	170.0	22.0	12.96	44.2	15.6
21	175.2	12.0	6.76	48.2	8.4
22	169.0	9.6	5.64	55.2	6.8
24	120.0	0.6	0.50	67.7	0.6

Table 4. Contd.

Breeding line	No. of eggs laid	No. of F1 adults emerged	% F1 emergence	Days to adult emergence	No. of seeds damaged
24-1	177.0	4.0	2.32	52.4	3.0
24-2	162.4	2.6	1.37	32.3	2.4
24-3	175.6	5.0	2.86	51.2	3.8
24-5	188.8	2.4	1.24	49.0	2.0
24-6	150.8	1.6	1.03	46.5	1.2
25	165.6	13.6	8.18	47.4	9.8
RAZ 25-1	128.2	0.0	0.00	-	0.0
25-2	128.2	0.2	0.13	63.0	0.2
25-3	165.6	21.4	13.39	46.6	12.6
27	73.2	5.6	7.48	50.6	4.2
28	142.0	9.6	6.47	47.8	8.0
29	153.6	16.0	10.58	46.8	10.0
30	166.2	7.4	4.71	47.8	5.6
Susceptible Check					
Natal Sugar	177.2	148.8	84.06	31.4	28.4

Acanthoscelides

Table 5 summarizes the results of the screening tests. Except in a few cases the number of adults that emerged from the RAZ lines were not significantly different from the susceptible check. Although significantly fewer insects developed on lines 8, 17 - 6, 17 - 7, 19, 21 and 25 -1 the numbers were unacceptably high (71.2 - 104.2). In contrast, significantly more insects developed from lines RAZ 4 - 2 and RAZ 9 - 4 compared to the susceptible check variety. There were no significant differences in damage levels between the RAZ lines and check variety.

As with the findings at CIAT the bruchid resistance lines showed only preferential resistance to *Zabrotes* and not to *Acanthoscelides*, the most dominant species in Africa. A significant impact of resistant varieties will therefore only be felt in Africa with the incorporation of resistance to *Acanthoscelides*. Unfortunately the development of resistant varieties is proving to be very difficult.

Table 5. Effects of "RAZ" cultivars on the biology of *A. obtectus*.

Breeding line	No. of F_1 adults emerged	Days to adult emergence	No. of seeds damaged
RAZ 4-2	188.2[b]	41.7	25.8
5	148.0	40.8	26.8
7	117.2	47.4	22.4
8	71.2[a]	44.8	16.2
9	151.6	40.6	27.2
9-1	168.8	45.4	27.2
9-2	114.0	43.2	24.0
9-4	204.8[b]	41.8	27.8
10	142.6	44.2	26.0
11	107.6	47.6	19.0
11-1	128.2	43.8	23.6
12	138.2	45.2	24.2
12-1	149.8	44.2	24.8
12-4	138.8	43.8	24.0
13	142.6	42.2	25.4
13-1	127.6	44.2	25.8
13-2	150.4	43.2	27.8
13-3	106.2	45.6	22.2
13-4	143.8	44.4	27.4
13-5	165.4	45.8	27.6
13-6	152.4	42.4	25.6
14	131.6	44.0	23.2
14-1	159.8	42.4	24.4
15	132.2	45.8	25.0
16	135.8	43.6	25.0
17	143.8	44.6	26.0
17-1	133.0	47.0	24.8
17-2	129.0	45.6	26.6
17-3	116.8	45.6	24.4
17-5	115.8	47.2	20.4
17-6	100.2[a]	46.2	23.6
17-7	104.2[a]	45.2	21.2
18	115.2	44.8	21.8
18-1	122.6	46.6	20.0
19	84.0[a]	46.6	20.2

Table 5. Contd.

Breeding line	No. of F_1 adults emerged	Days to adult emergence	No. of seeds damaged
20-1	119.0	43.6	22.6
20-2	128.8	41.2	23.8
21	100.6[a]	44.2	23.2
22	114.0	44.6	19.4
24	124.2	48.2	21.0
24-1	123.4	47.4	24.4
24-2	159.4	47.2	26.8
24-3	169.2	45.4	26.8
24-5	120.6	47.4	23.6
24-6	169.6	46.6	27.0
25	137.8	45.6	24.4
25-1	90.6[a]	43.2	21.2
25-2	134.2	44.6	24.2
25-3	149.4	44.6	25.4
27	153.0	42.8	25.6
28	181.0	41.8	27.8
29	130.4	43.6	23.4
30	116.2	46.2	22.6
Susceptible Check			
Natal Sugar	135.8	37.8	25.0

[a]RAZ cultivar on which F_1 emergence was significantly ($P = 0.05$) less than on susceptible Natal Sugar.
[b]RAZ cultivars on which F_1 emergence was significantly ($P=0.05$) greater than on susceptible Natal Sugar.

BRUCHID POPULATIONS IN THE FIELD AND INFESTATION OF PODS

Experiments were conducted to determine:

- bruchid species and population levels in the field
- infestation of pods in the field and after harvest
- ability of *Zabrotes* and *Acanthoscelides* to attack
- dry pods kept in storage for varying periods
- infestation levels on pods in relation to length of storage with time in store.

Natal Sugar beans were planted on 13/1/91 in two plots (40 x 12 m) at the University of Zimbabwe and monitored regularly for bruchids. Twenty meters of every alternate row of each of the two plots were sampled weekly using a D-vac suction sampler. Bean pods were randomly harvested weekly over several weeks. The bean pods from each sample were artificially infested with the two species of bruchids and after 6 weeks of incubation at ambient conditions the number of insects that developed was counted. Pods without artificial infestations were also incubated to determine whether infestations had established in the field.

A second trial of nine cultivars was planted during the same season at Domboshawa, and pods of each cultivar were randomly harvested over several weeks. One pod of each cultivar was infested with four pairs of randomly selected insects and incubated under ambient conditions for 6 weeks after which time the number of insects that developed were counted. The pods were infested separately with *Zabrotes* and *Acanthoscelides* and replicated 10 times. At the same time pods with no artificial infestations were also set up.

During the 1992/93 season Natal Sugar beans were planted at the University of Zimbabwe in a 120 x 40 m plot. Pods were sampled weekly after maturity and incubated at ambient conditions for 6 weeks and insect populations counted. After harvest the pods were stored in a jute bag placed in a shed and the same procedure, of regular sampling and incubation, was followed.

Half of the harvest was threshed and also stored in a jute sack. Three samples of 50 g of beans were also collected at each sampling occasion and incubated. The number of insects that emerged were counted.

Results and Discussion

The number and species of bruchids collected by the D-vac sampler are given in Table 6. Whilst *C. rhodesianus* and *Acanthoscelides* were the most numerous and increased after pod initiation few *Bruchidius* species and no *Zabrotes* were recorded.

Table 6. The bruchid species and populations sampled with time.

Date	*Anthoscelides obtectus*	*Zabrotes subfasciatus*	*Collosobruchus maculatus*	*C. rhodesianus*	*Bruchidius* spp.
31 Jan 92	3	0	0	0	0
7 Feb	8	0	1	0	1
14 Feb	0	0	3	3	1
21 Feb	2	0	0	10	0
28 Feb	8	0	0	32	0
6 Mar	1	0	0	57	5
13 Mar	8	0	2	41	4
23 Mar	9	0	0	31	0
27 Mar	23	0	0	52	0
3 Apr (harvest)	31	0	0	19	0

No *Zabrotes* emerged from any of the pods, whether artificially infested or not. These results confirm that *Zabrotes* does not occur in the highveld (1250 m) in Zimbabwe and that the species is unable to infest beans in the pod. However, those pods that were split with beans exposed became infested. In contrast, *Acanthoscelides* was easily able to breed on pods of each of the cultivars (Table 7) irrespective of when they were harvested. More insects developed from split pods due to the easy entry of larvae.

Table 7. Mean number of *A. obtectus* adults developed from artificially infested pods of different varieties.

Date (1992)	EMP 150	P 152	CAN 31	PAN 10	BAT 1775	Natal Sugar	RAB 303	Carioca	Red Canadian Wonder
21 Feb	27.2	24.4	32.4	27.5	25.9	22.1	34.2	35	38.4
28 Feb	12.2	21.0	3.4	16.0	9.6	25.2	5.6	0	9.8
6 Mar	1.6	0	0.4	2.4	0.2	11.2	1.0	5.2	4.6
13 Mar	39.6	41	48.2	42.2	39.6	45.6	35.6	38.6	3.8
20 Mar	4.4	1.2	8.2	2.4	6.6	0	0	3.6	1.0
27 Mar	32.0	14.8	20.8	22.0	21.6	19.8	20.8	12.0	15.6
3 Apr	13.0	22.8	20.4	17.2	20.2	11.0	16.0	17.8	19.2
10 Apr	28.2	13.6	21.8	14.6	14.8	17.8	21.4	15.4	8.2
16 Apr	2.6	12.0	14.6	15.4	15.4	2.6	10.2	2.6	19.8
24 Apr	5.8	5.2	10.2	12.6	19.8	8.0	14.6	10.2	11.6
26 Jun	0.8	9.2	8.2	15.4	7.2	2.8	0	0	1.2
10 Jul	0	2.4	9.6	1.0	2.0	0	0	0	6
17 Jul	2.0	0	0.4	0	0	0.2	0	0	2.6
31 Jul	17	19.6	6.2	4.6	14.0	3.0	10.8	9.4	20.4
14 Aug	1.8	0	15.2	6.2	7.2	3.2	2.0	0.4	30.0
28 Aug	3.8	10.4	1.6	2.0	9.4	12.2	14.4	7.2	7.4

Table 8 shows the number of adult *Acanthoscelides* that emerged from naturally infested pods collected from the field and from storage at different times. Field infestation based on the samples collected was about 10% and increased to 60 - 70% in storage at the end of the trial. The number of insects that emerged from the pods, however, would be expected to be lower than from threshed seed. Fifty gram samples of beans collected weekly from storage over a six-week period on average produced 30 adults.

EVALUATION OF AMORPHOUS SILICA DUST (DRYACIDE)

A commercial preparation of an amorphous silica dust (trade name Dryacide) from Australia was tested as a grain protectant applied at rates of 1 and 2 g silica dust/kg beans against the two species of bruchid. The efficacy of the dust was compared with 2% dust formulations of pirimiphos-methyl and methacrifos at 10 mg/kg beans. Bioassays were conducted on treated beans aged for 0, 12 and 24 weeks and mortalities assessed after exposure periods of 2, 5 and 7 days.

Table 8. Percentage of pods infested and mean number of *A. obtectus* adults emerged from pods sampled from the field and from storage.

Date	Percentage pods infested	Mean number insects emerged
15 Apr 91	10	3.1
16 Apr 91	10	0.6
24 Apr 91	10	0.3
22 May 91	0	0
29 May 91	10	1.8
11 Jun 91	30	1.8
12 Jun 91	40	3.4
3 Jul 91	10	1.7
10 Jul 91	20	2.3
17 Jul 91	70	7.1
26 Jul 91	20	3.4
31 Jul 91	60	13.8
14 Aug 91	40	12.5
28 Aug 91	60	18.6

Results and Discussion

The results of insect mortality are given in Table 9. No insects survived the 5 and 7 day exposures in all treatments. The toxic effects of methacrifos and pirimiphos-methyl on *Zabrotes* decreased slightly with age of treatment and required more than a 2 day exposure to achieve a 100% kill. In all treatments, a 100% mortality was achieved after the 5 and 7 day exposure periods in both species. No progeny developed in any of the treatments. In the untreated control a mean of 147 adults emerged resulting in over 80% grain damage. Dryacide is an ideal substitute to dilute/dust insecticides for the small farmer.

SOLAR DISINFESTATION

Exposure of grain at regular intervals to the sun to control bruchids is a common practice in Africa. The heat from the sun tends to drive out adult bruchids, kills eggs and early stage larvae. However the success of this method of disinfestation depends on the temperature to which the grain is heated and the frequency and length of exposure.

Beans were infested with *Zabrotes* for 21 days then placed on either a clear or black polythene sheet, or on a black polythene sheet covered with a clear sheet and exposed to sunlight for 5 hours for 0, 3 and 5 days. After these exposure times the beans were incubated under ambient conditions and the number of insects that emerged were compared with the control. The percentage damage in each of the treatments was also measured.

Table 9. Mortality of *Z. subfasciatus* and *A. obtectus* (in parentheses) on beans treated with Dryacide and insecticides after different periods of storage.

Treatment	Percent mortality exposure time (days)		
	2	5	7
Fresh deposit:			
10 mg/kg P-methyl	100 (100)	100 (100)	100 (100)
10 mg/kg Methacrifos	100 (100)	100 (100)	100 (100)
1 g/kg Dryacide	100 (86)	100 (100)	100 (100)
2 g/kg Dryacide	100 (98)	100 (100)	100 (100)
12 weeks old deposit:			
10 mg/kg P-methyl	82 (100)	100 (100)	100 (100)
10 mg/kg Methacrifos	84 (100)	100 (100)	100 (100)
1 g/kg Dryacide	96 (88)	100 (100)	100 (100)
2 g/kg Dryacide	100 (92)	100 (100)	100 (100)
24 weeks old deposit:			
10 mg/kg P-methyl	78 (100)	100 (100)	100 (100)
10 mg/kg Methacrifos	88 (100)	100 (100)	100 (100)
1 g/kg Dryacide	66 (72)	100 (100)	100 (100)
2 g/kg Dryacide	100 (100)	100 (100)	100 (100)

Results and Discussion

Table 10 summarizes the results of insect emergence and damage. Clearly the highest number of insects emerged in the control, i.e., from beans not exposed to solar radiation. Insect populations were significantly reduced in all treatments; the longer the exposure time the better the control. Enclosing the beans in a "solar heater" resulted in total control. No insects emerged from beans placed on the heat absorbing black polythene sheet as well. Similarly, damage levels were highest in the control (80.5%), and were significantly reduced when the beans were exposed to solar heat. Beans exposed for longer periods on the black sheet and the clear/black sheet (solar heater) incurred zero damage.

Our results demonstrate that in using solar energy, temperatures of beans kept in simple solar heaters can easily be raised to cause significant mortality of all stages of insects developing within the seeds. While much research remains to be done to adapt the principle to the materials and conditions prevailing in different regions, it seems clear that the approach has promise for bruchid control.

Table 10. Effect of solar-disinfestation on the number of *Z. subfasciatus* emerged and percent damage of infested seed exposed to solar heat for 0, 3 and 5 - five hour days.

Treatment	Duration of exposure (days x 5 h)	Number of adults emerged	Percent seed damaged
Control	0	5250 ± 534.1	80.5 ± 4.5
Clear polythene	3	1502 ± 489.1	32.2 ± 6.6
Black polythene	3	33 ± 9.2	10 ± 0.4
Sheet	5	0	0
Black + clear	3	0	0
Polythene sheet	5	0	0

COMPETITION

Competition among and within species has been suggested to be important in determining distributions of pests, although many entomologists believe the importance of competition between storage pests is often exaggerated. In laboratory experiments inter- and intra-specific competition and species interactions are important regulatory factors influencing the population dynamics of the pests. Field observations in Tanzania showed the presence of either one species alone or when the two species were present there was a predominance of either species depending on temperature. In order to explain these effects, competition studies were conducted at different temperatures. Because of the adaptation of *Acanthoscelides* to lower temperatures it is expected to be a stronger competitor in cooler, higher altitude environments. In contrast, *Zabrotes* is expected to be the stronger competitor and more predominant in warmer tropical areas.

Three experiments were performed to study competition:

(i) short term - one generation experiments based on the replacement series design to predict the outcome of interspecific competition at 22°C, 28°C and 32°C.
(ii) long term studies in which the species were allowed to compete on fixed (limited) food resources at 22°C and 28°C.
(iii) long term experiments in which the two species were allowed to compete with food resources being replenished every 6 weeks at 22°C and 32°C.

All experiments were maintained at 60 - 70% relative humidity. The long term experiments were done to verify the predictions made from the replacement series experiments.

Results and Discussion

Only a summary of the results are presented here. The replacement series design proved to be a useful and quick method for predicting the outcome of competition between the bean bruchids. Based on the form of the reproduction curves of the two species in single and mixed species populations, predictions on whether a species would be outcompeted or whether it would predominate were made. Based on the reproduction curves of single species the intrinsic rates of increase (r) and carrying capacities (K) were estimated. At 22, 28 and 32°C the estimated r values were 0.750, 1.21 and 0.32

respectively for *Acanthoscelides*, while for *Zabrotes* the estimated *r* values were 0.609, 0.951 and 1.10 respectively. The replacement series experiments showed that at 22°C and 28°C *Acanthoscelides* was the stronger competitor while at 32°C *Zabrotes* was the stronger competitor of the two species. It is predicted that at 22°C and 28°C *Zabrotes* would eventually become extinct in the long term. However, at 32°C there is a reversal in the outcome of competition in that *Zabrotes* appeared to be the dominant competitor and is likely to drive out *Acanthoscelides*.

In the long term experiments, population growth over time of *Zabrotes* was very low at 22°C and 28°C compared to that of *Acanthoscelides*. At 22°C in two of the three experiments performed *Zabrotes* became extinct after 35 days and at 28°C it remained at low densities throughout the duration of the experiment. The dominance of one species over another is not only due to its adaptation to prevailing temperatures but also to the interactions between species.

CONCLUSION

The above is a brief summary of our research activities of the bruchid sub-project funded by SADC/CIAT and a Rockefeller Foundation grant. The experimental details of the experiments above are not presented here due to limited space.

Several objectives of the original proposal and questions posed in this paper need to be addressed. Also more detailed work on some of the control strategies proposed needs to be verified in on-farm situations.

DISCUSSION

Nyirenda : I suggest that we have some individuals trained in the identification of bean bruchids and other bean insects.

Slumpa : What about the possibility of sending samples to a central lab for identification.

Giga : There are already some keys developed for species identification. I was supposed to do a postal survey of bruchid species distribution in the region. I requested for samples but received none.

VEGETABLE AND NEEM OILS AS PROTECTANTS OF STORED BEANS AGAINST BRUCHIDS

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ABSTRACT

Two commercial vegetable oil brands and neem oil applied at 2.5, 5.0 and 7.5 ml/kg-1 seed were evaluated for their effectiveness in controlling bruchids. Evaluations were done at 0, 8 and 16 weeks after oil application. All vegetable oil treatments resulted in >90% insect mortalities within 7 days of exposure of weevils to freshly treated seeds. On the other hand, all fresh neem oil treatments resulted in 100% adult mortalities within the same period. Only neem oil retained its toxic effect on adult insects after storage for 8 and 16 weeks.

All oil treatments reduced oviposition, percent egg hatch, progeny emergence and seed damage levels. Though vegetable oil treatments were very effective seed protectants for the period investigated, periodic re-applications may be necessary if much longer storage periods are desired.

INTRODUCTION

Though the use of plant oils as grain protectants dates back to ancient Indian times, their use in seed storage has not expanded much chiefly because man still relies heavily on conventional insecticides. Interest in oils has, however, been renewed due to their suitability as adjuvants to improve insecticide and acaricide efficacy especially in ultra low volume (ULV) and controlled droplet application (CDA) systems (Hessler and Plapp, 1986).

Schoonhoven (1978) confirmed the effectiveness of vegetable oils for bruchid control. Further work by Hill and Schoonhoven (1981) and Don-Pedro (1990) showed that vegetable oil fractions alone were toxic to bruchids. Other workers (Pereira, 1983; Messina and Renwick, 1983; Giga and Munetsi, 1990) also demonstrated the usefulness of vegetable oils as general protectants of pulses. Coconut and groundnut oils have been shown to prevent infestation of stored maize by rice weevils, *Sitophilus oryzae* L. for at least 3 months (Ivbijaro *et al.*, 1985). Evidence has shown that oils act primarily as ovicides and physical poisons which interfere with respiration in the egg and in adult insects. Egg mortality is thought to arise from the accumulation of a gaseous metabolite which is prevented from passing out through the chorion.

Other plant oils such as neem oil have been shown to possess pesticidal activity as antifeedants, repellents, toxins, and development inhibitors (Attri and Prasad, 1980). Concentrations as low as 1 ml oil/kg-1 have been shown to significantly reduce populations of *Tribolium confusum* Duv. and *Sitophilus zeamais* Motsch in maize seed by having a strong repellency effect (Akou-Edi, 1984). Similarly, Zehrer (1984) showed that neem oil could protect cowpeas for as long as 10 months against *C. maculatus* without affecting seed viability.

This study evaluates two local vegetable oil brands and neem oil as seed protectants against *Z. subfasciatus* and *A. obtectus*.

MATERIALS AND METHODS

Neem-seed oil and two commercial vegetable oil brands were used in the study. The neem oil was a commercial concentrate marketed by Gharda Chemicals Ltd, Bombay, India, under the trade name "Neemguard". The two vegetable oils comprised a sunflower seed oil extract and a cotton seed and soya oil blend.

All seeds were initially equilibrated to experimental conditions of temperature 27 ± 1°C and 60 70% RH for at least two weeks. Bioassays were also conducted under these conditions.

Amounts of oil calculated to give dosages of 2.5, 5.0 and 7.5 ml/kg-1 seed were pipetted on to 400 g samples of seeds in 11 glass jars. Treated seeds were then shaken thoroughly for about 3 minutes to ensure effective coating of seeds with oil. Following mixing, five 25 g sub-samples were withdrawn from each jar and placed in smaller jars with perforated metal lids. Five untreated replicates were also prepared simultaneously. Thus each treatment, including the control was replicated five times. Each jar was then infested with five pairs of freshly emerged (0-24 h old) male and female *Z. subfasciatus* adults. The remaining seeds were stored at room temperature till required for further tests after allowing the treatments to age for 8 and 16 weeks respectively. Seeds for infestation with *A. obtectus* were similarly prepared except that unsexed adults were used.

The effects of the different oil treatments were assessed by recording mortality (7 days after infestation), percent egg hatch, F_1 emergence and percent seed damage.

Two weeks after infestation, all remaining insects (dead and alive) were removed, and a week later, the number of hatched (white) and unhatched (transparent) eggs were counted (for *Z. subfasciatus* infestations only). The percentage of hatched eggs (larvae entering the seed) and the total percentage survival to emergence as adults were calculated for each treatment. Treatments were then left undisturbed until the emergence of the first adult progeny, from which time insects were removed and counted every second day until emergence was complete. The percentage of damaged (holed) seeds was also calculated for each replicate.

The residual activity of the oils were assessed in similar experiments in which adult insects were placed on seeds 8 and 16 weeks after treatment. For each infestation, a new set of controls was used.

RESULTS

Mortality

All fresh oil treatments caused very high mortalities of adult insects of both species (Table 1). At dosage rates of 5.0 and 7.5 ml/kg-1, 100% mortality was achieved within a 7-day exposure. At the lowest dosage rate (2.5 ml/kg-1), the vegetable oils achieved insect mortalities of at least 90%. In contrast, all neem oil treatments resulted in 100% insect mortalities. Overall, all fresh oil treatments showed insignificant dosage-effect differences as the lowest dosage rate resulted in mortalities statistically similar to that due to the two higher rates.

Table 1. Percent mortality of (a) *Z. subfasciatus* and (b) *A. obtectus* adults exposed to seeds treated 0, 8 and 16 weeks before infestation.

Treatment	Dose [ml/kg-1]	Age of deposit (weeks)		
		0	8	16
(a) *Z. subfasciatus*:				
Control	0.0	6.0 (0.7558)	4.0 (0.6093)	6.0 (0.7558)
	2.5	90.0 (3.0148)	12.0 (1.1289)	12.0 (1.1289)
Sunflower	5.0	100 (3.1780)	14.0 (1.2089)	18.0 (1.3513)
	7.5	100 (3.1780)	8.0 (0.8358)	20.0 (1.4314)
Cotton	2.5	94.0 (3.0794)	14.0 (1.1425)	12.0 (1.1289)
Soya	5.0	100 (3.1780)	18.0 (1.3691)	18.0 (1.3513)
	7.5	100 (3.1780)	14.0 (1.1425)	26.0 (1.5932)
	2.5	100 (3.1780)	100 (3.1780)	86.0 (2.9395)
Neem	5.0	100 (3.1780)	100 (3.1780)	100 (3.1780)
	7.5	100 (3.1780)	100 (3.1780)	100 (3.1780)
Least significant differences between:				
Dose rate means		0.4619 (P = 0.001)	0.4242 (P = 0.05)	0.3803 (P = 0.05)
Treatment means		0.2310	0.2121	0.1901
(b) *A. obtectus*:				
Control	0.0	4.0 (0.5428)	2.0 (0.4627)	6.0 (0.6893)
	2.5	96.0 (3.1116)	8.0 (0.8358)	0.0 (0.3162)
Sunflower	5.0	100 (3.1780)	2.0 (0.4627)	0.0 (0.3162)
	7.5	100 (3.1780)	4.0 (0.6093)	0.0 (0.3162)
Cotton	2.5	100 (3.1780)	4.0 (0.6093)	0.0 (0.3162)
Soya	5.0	100 (3.1780)	10.0 (0.9824)	0.0 (0.3162)
	7.5	100 (3.1780)	8.0 (0.8358)	0.0 (0.3162)
	2.5	100 (3.1780)	100 (3.1780)	84.0 (2.9143)
Neem	5.0	100 (3.1780)	100 (3.1780)	96.0 (3.1135)
	7.5	100 (3.1780)	100 (3.1780)	98.0 (3.1458)
Least significant differences between:				
Dose		0.5710 (P = 001)	0.4382 (P = 0.05)	0.3417 (P = 0.05)
Treatment means		0.2855	0.2191	0.1708

Statistical analyses were based on $\sqrt{(\text{counts}+0.1)}$ data (in parentheses)

Vegetable oil deposits aged for 8 and 16 weeks respectively generally had no effect on adult insects even though some mortalities were recorded in both species. Only neem oil showed residual activity. Mortalities recorded in 8- and 16-week old neem oil deposits were generally not significantly ($P = 0.05$) different from those due to fresh deposits. Also, as with fresh deposits, neem oil treatments showed insignificant dosage-effect differences. Overall, treatment x dosage interaction effects became significant as oil deposits aged.

Percent egg hatch (*Z. subfasciatus*)

The admixture of oils at all three dosage rates severely depressed oviposition on freshly treated seeds (Table 2). Oviposition only occurred on seeds treated with 2.5 ml vegetable oil kg-1 but less than 11% percent of the eggs hatched.

Table 2. The effect of oil treatments on (a) number of eggs laid and (b) percent egg hatch in *Z. subfasciatus.*

Treatment	Dose [ml/kg-1]	Age of deposit (weeks)		
		0	8	16
(a) Number of eggs*				
Control	0.0	232.8	183.2	183.4
	2.5	74.0	106.4	117.2
Sunflower	5.0	0.0	150.8	100.4
	7.5	0.0	92.8	110.6
Cotton	2.5	66.0	140.2	119.4
Soya	5.0	0.0	132.4	147.0
	7.5	0.0	134.4	144.6
	2.5	0.0	8.2	0.0
Neem	5.0	0.0	0.2	0.0
	7.5	0.0	0.0	0.0

*Data not analyzed.

Table 2. Contd.

Treatment	Dose [ml/kg-1]	Age of deposit (weeks)		
		0	8	16
(b) Percent egg hatch				
Control	0.0	90.1 (1.2533)	84.0 (1.1611)	79.7 (1.1154)
	2.5	10.9 (0.3276)	34.6 (0.6246)	61.4 (0.9014)
Sunflower	5.0	0.0 (0.0000)	39.4 (0.6765)	68.6 (0.9764)
	7.5	0.0 (0.0000)	28.1 (0.5568)	55.5 (0.8421)
Cotton	2.5	9.5 (0.3097)	44.7 (0.7323)	47.1 (0.7548)
Soya	5.0	0.0 (0.0000)	29.1 (0.5686)	28.8 (0.5663)
	7.5	0.0 (0.0000)	21.2 (0.4735)	41.4 (0.6687)
	2.5	0.0 (0.0000)	0.0 (0.0000)	0.0 (0.0000)
Neem	5.0	0.0 (0.0000)	0.0 (0.0000)	0.0 (0.0000)
	7.5	0.0 (0.0000)	0.0 (0.0000)	0.0 (0.0000)
Least significant differences between:				
Dose		0.0943 (P = 001)	0.0832 (P = 0.05)	0.1423 (P = 0.05)
Treatment means		0.0472	0.0417	0.0712

Statistical analyses were based on arcsine-transformed data (in parentheses).

After 8 and 16 weeks respectively, all neem oil treatments were still very effective and resulted in zero percent egg hatch. In contrast, 8- and 16-week old vegetable oil deposits were not as effective as fresh treatments thus oviposition and percent egg hatch increased though they were still significantly lower (P = 0.05) than on the untreated controls. The analyses of variance of data revealed insignificant dosage effect differences.

Progeny emergence and seed damage

The results (Tables 3 - 5) show that F_1 adult emergence and percent seed damage were significantly (P = 0.05) reduced in all oil treatments. Neem oil was the most effective and resulted in zero F_1 emergence. For *Z. subfasciatus*, both %F_1 emergence (survival of eggs to emergence) and mean F_1 adult numbers (Table 3) were significantly reduced (P = 0.05) by aged vegetable oil treatments. Dosage- and age-effect differences were also evident between fresh and aged vegetable oil deposits.

Highly significant (P = 0.001) treatment x dosage interaction effects were obtained with aged oil treatments on *Z. subfasciatus*. This implies that the reduction in F_1 insect emergence and seed damage levels differed as to the type and dosage of oil used. In the case of *A. obtectus*, treatment x dosage interaction effects were not significant (P = 0.05). Overall, the vegetable oils did not differ statistically in their effects.

Table 3. Effect of oil treatments on (a) number of adults emerged and (b) percent emergence of *Z. subfasciatus*.

Treatment	Dose [ml/kg-1]	Age of deposit (weeks)		
		0	8	16
(a) Number of F_1 adults				
Control	0.0	125.6 (11.0881)	124.0 (11.1493)	128.2 (11.2534)
Sunflower	2.5	4.8 (2.2186)	9.4 (3.0336)	25.4 (5.0335)
	5.0	0.0 (0.7071)	8.2 (2.9002)	8.2 (2.8547)
	7.5	0.0 (0.7071)	1.6 (1.3718)	3.0 (1.7459)
Cotton	2.5	2.4 (1.5503)	16.4 (3.7857)	27.4 (4.8793)
Soya	5.0	0.0 (0.7071)	6.8 (2.3871)	11.2 (3.3423)
	7.5	0.0 (0.7071)	0.2 (0.8106)	2.0 (1.3584)
Neem	2.5	0.0 (0.7071)	0.0 (0.7071)	0.0 (0.7071)
	5.0	0.0 (0.7071)	0.0 (0.7071)	0.0 (0.7071)
	7.5	0.0 (0.7071)	0.0 (0.7071)	0.0 (0.7071)
Least significant differences (P = 0.01) between:				
Dose rate means		1.7641	1.3409	1.9774
Treatment means		0.8821	0.6705	0.9887

Statistical analyses were based on $\sqrt{(x+0.5)}$ data (in parentheses)

Treatment	Dose [ml/kg-1]	0	8	16
(b) Percent F_1 emergence*				
Control	0.0	59.3 (0.8792)	80.4 (1.1123)	6.0 (0.6893)
Sunflower	2.5	61.4 (0.9088)	29.8 (0.5553)	0.0 (0.3162)
	5.0	0.0 (0.0000)	14.2 (0.3805)	0.0 (0.3162)
	7.5	0.0 (0.0000)	5.8 (0.2027)	0.0 (0.3162)
Cotton	2.5	31.7 (0.4899)	22.2 (0.4423)	0.0 (0.3162)
Soya	5.0	0.0 (0.0000)	13.5 (0.3571)	0.0 (0.3162)
	7.5	0.0 (0.0000)	0.5 (0.0330)	0.0 (0.3162)
Neem	2.5	0.0 (0.0000)	0.0 (0.0000)	84.0 (2.9143)
	5.0	0.0 (0.0000)	0.0 (0.0000)	96.0 (3.1135)
	7.5	0.0 (0.0000)	0.0 (0.0000)	98.0 (3.1458)
Least significant differences between:				
Dose rate means		0.3362 (P = 001)	0.1601 (P = 0.05)	0.1359 (P = 0.05)
Treatment means		0.1681	0.0800	0.0679

* Total number of adults emerged/number of eggs hatched.
Statistical analyses were based on arcsine-transformed data (in parentheses)

Table 4. Effect of oil treatments on the number of *A. obtectus* adults emerged.

Treatment	Dose [ml/kg-1]	Age of deposit (weeks)		
		0	8	16
Control	0.0	78.4 (8.5833)	53.0 (7.0075)	51.0 (6.9842)
Sunflower	2.5	0.0 (0.7071)	2.8 (1.6360)	8.4 (2.8118)
	5.0	0.0 (0.7071)	0.4 (0.9142)	0.2 (0.8106)
	7.5	0.0 (0.7071)	1.0 (1.0347)	3.6 (1.7834)
Cotton	2.5	2.6 (1.5780)	1.2 (1.1648)	6.2 (1.9117)
Soya	5.0	0.0 (0.7071)	10.6 (2.8637)	6.8 (2.3346)
	7.5	0.0 (0.7071)	6.4 (2.2082)	12.6 (2.9672)
Neem	2.5	0.0 (0.7071)	0.0 (0.7071)	0.0 (0.7071)
	5.0	0.0 (0.7071)	0.0 (0.7071)	0.0 (0.7071)
	7.5	0.0 (0.7071)	0.0 (0.7071)	0.0 (0.7071)
Least significant differences between:				
Dose rate means		2.8952 (P = 001)	1.8166 (P = 0.05)	1.8045 (P = 0.05)
Treatment means		1.4476	0.9083	0.9023

Statistical analyses were based on $\sqrt{(x+0.5)}$ data (in parentheses)

Table 5. Effect of oil treatments on percent seed damage by (a) *Z. subfasciatus* and (b) *A. obtectus*

Treatment	Dose [ml/kg-1]	Age of deposit (weeks)		
		0	8	16
(a) *Z. subfasciatus*				
Control	0.0	72.7 (1.0261)	78.7 (1.0986)	79.7 (1.1226)
Sunflower	2.5	3.9 (0.1946)	6.5 (0.2534)	12.2 (0.3537)
	5.0	0.0 (0.0000)	5.7 (0.2375)	5.1 (0.2203)
	7.5	0.0 (0.0000)	2.1 (0.1293)	2.1 (0.1295)
Cotton	2.5	1.8 (0.1025)	8.2 (0.2590)	15.1 (0.3746)
Soya	5.0	0.0 (0.0000)	4.5 (0.1944)	7.8 (0.2762)
	7.5	0.0 (0.0000)	0.4 (0.0265)	1.4 (0.0764)
Neem	2.5	0.0 (0.0000)	0.0 (0.0000)	0.0 (0.0000)
	5.0	0.0 (0.0000)	0.0 (0.0000)	0.0 (0.0000)
	7.5	0.0 (0.0000)	0.0 (0.0000)	0.0 (0.0000)
Least significant differences between:				
Dose rate means		0.1406 (P = 001)	0.1057 (P = 0.05)	0.1516 (P = 0.05)
Treatment means		0.0703	0.0529	0.0758
(b) *A. obtectus*				
Control	0.0	50.3 (0.7854)	39.4 (0.6733)	40.3 (0.6848)
Sunflower	2.5	0.0 (0.0000)	3.7 (0.1507)	8.9 (0.2885)
	5.0	0.0 (0.0000)	0.8 (0.0552)	0.4 (0.0276)
	7.5	0.0 (0.0000)	1.1 (0.0480)	4.4 (0.1539)
Cotton	2.5	1.1 (0.0797)	1.5 (0.0767)	4.3 (0.1477)
Soya	5.0	0.0 (0.0000)	6.9 (0.2273)	6.8 (0.2061)
	7.5	0.0 (0.0000)	3.6 (0.1484)	9.1 (0.2539)
Neem	2.5	0.0 (0.0000)	0.0 (0.0000)	0.0 (0.0000)
	5.0	0.0 (0.0000)	0.0 (0.0000)	0.0 (0.0000)
	7.5	0.0 (0.0000)	0.0 (0.0000)	0.0 (0.0000)
Least significant differences between:				
Dose rate means		0.2742 (P = 001)	0.1662 (P = 0.05)	0.1683 (P = 0.05)
Treatment means		0.1371	0.0831	0.0841

Statistical analyses were based on arcsine-transformed data (in parentheses)

DISCUSSION

The results of this study show that oils are effective surface protectants of beans against bruchids. All oils significantly reduced percent egg hatch, progeny emergence and seed damage. While the protective effect on newly treated seeds was mainly due to high adult mortalities, subsequent protection as the treatments aged was achieved by a combination of reduced oviposition, ovicidal and larvicidal effects (Pereira, 1983).

The results are also in agreement with the findings of Schoonhoven (1978), Messina and Renwick (1983), and Don-Pedro (1989) and (1990). Hill and Schoonhoven (1981) concluded that the principal insecticidal action of oils depended mainly on ovicidal activity; this being the result of a general physical property of oil coating rather than specific chemical action. However, the highly significant and persistent effect of neem oil on adult mortality and egg survivorship to emergence as adults may suggest the presence of a specific chemical component which is retained on seed taste. This chemical component is retained in very high concentrations such that even very low oil dosage rates are quite effective.

It is evident from the results of this study that oils admixed with seeds can significantly reduce damage by bruchids. Although the treatment is unlikely to stop re-infestation of seeds (with the possible exception of neem oil), the short term protection is very important as it stops population growth from pre-harvest infestation. However, effective protection of seeds could be guaranteed throughout the desired storage period by carefully timed re-applications or single higher dosage applications. Previous studies have shown that oil treatments do not affect germination (Schoonhoven, 1978; Singal and Singh, 1990) but rancidity (Schoonhoven, 1978) could have an adverse effect on taste. Therefore, oil treatments could be more useful if targeted on seeds intended for planting. The technique would be quite useful for the protection of small quantities of grain at the small farmer level where sanitation is minimal and inspection irregular.

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DISCUSSION

Agona	:	Using oils can cause rancidity on seeds. How are you going to deploy this control method?
Chinwada	:	The method will be suitable for planting materials.
Ampofo	:	To what extent are farmers using oils and if not why not ?
Nahdy	:	Oils are effective in labs but field problems arise with the quantities that need to be applied.
Kabungo	:	Why did you have to use cotton, soya and sunflower oils alone?
Chinwada	:	They are the commercial blends available.
Gethi	:	What is the cost of this control method?
Chinwada	:	They are quite cheap compared to insecticides but not suitable for large quantities of beans.
Agona	:	How can the efficiency of oils be maintained throughout storage?
Youngquist	:	With any product you generally expect a decline in effectiveness with time.

STUDIES ON THE CONTROL OF THE BEAN BRUCHIDS *ACANTHOSCELIDES OBTECTUS* (SAY) AND *ZABROTES SUBFASCIATUS* (BOHEMAN) (COLEOPTERA : BRUCHIDAE) IN THE EAST AFRICAN REGION

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ABSTRACT

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

INTRODUCTION

The two bruchids *Acanthoscelides obtectus* and *Zabrotes subfasciatus* are the most important pests of stored beans. These cause damage, weight loss, and a reduction in seed quality and viability. Losses in East Africa attributed to bruchid damage have been estimated at between 30 and 73% (Karel and Khamala, 1978). In Uganda loss levels of 3 and 8% in storage durations of 3 and 6 months respectively have been reported by Silim *et al.* (1991).

A. obtectus has been found to be the predominant species in the cooler region while *Z. subfasciatus* is the commonest species in the warmer environments (Van Schoonhoven and Cardona, 1986). Infestations by *A. obtectus* begin in the field and intensify in storage whereas *Z. subfasciatus* infestations often begin in storage (Silim, 1990 unpublished). *A. obtectus* oviposits in pods under field conditions or lays loosely among grains in storage. *Z. subfasciatus*, however, glues the eggs on the grain.

The most publicized method of bruchid control is the use of insecticides. This is, however, mostly unavailable or unaffordable by subsistence farmers. In addition, chemical insecticides have a limited shelf life and are prone to user abuse. Other control methods include bean resistance, use of oils and bean tumbling (Quentin *et al.*, 1991). Use of oils and bean tumbling, though found successful experimentally, may have limited adaptability due to their costs and the inconvenience of application. Other safe and reliable on-farm control strategies are essential.

Focus of research was therefore put on practices found at the on-farm level. These include solar heat treatment, bean sieving methods and other locally available protectants. On-farm trials were also conducted to establish the efficacy of sunning, sieving and vegetable oils on *A. obtectus* infestation.

A. FARMERS' PERCEPTION OF DAMAGE AND CONTROL OF BEAN BRUCHIDS IN UGANDA

Materials and Methods

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

Results and Discussion

The majority of the respondents were males in the age range of 20 to over 50 years and have been growing beans for 10 to over 30 years depending on individual age. Though two growing seasons were identified in all the bean growing areas, 34% of the farmers, mostly in agro-ecological zone III, grew beans in only one of the seasons. Bean production per family ranged between 50 - 300 kg per season.

Harvested beans were sun dried and threshed. Bean seeds were redried and stored for either home consumption, seed or for sale. Storage duration ranged from 1 - 4 months (41%), 5 - 8 months (90%) and for up to one year (9%). Bruchids were identified as the major storage concern. Most farmers

(56%) thought that some bean varieties are more susceptible to bruchid infestation than others. The smaller bean varieties were considered more resistant.

The commonest bruchid control strategy used by farmers was regular drying in the sun. Reinfestation after solar heat treatment was, however, considered rapid. Other bruchid control methods used other than chemical, include tobacco leaves, wood ash, banana juice and red pepper. Some 27% of farmers thought nothing could be done to control bruchids. The only method considered very effective was chemical control. Among the chemicals used were Actellic, Malathion, DDT and various other non-storage insecticides not recommended for storage. Most traditional methods were considered ineffectual and had other problems associated with their use like difficulty in cleaning, cooking, eating, etc.

B. RESISTANCE TRIALS ON *Z. SUBFASCIATUS* EVALUATION FOR RESISTANCE TO *Z. SUBFASCIATUS*

Materials and Methods

Four bean varieties were tested (RAZ 2, EMP 175, K 20 and white haricot). Beans were equally infested with four sexed pairs of newly emerged insects placed in cloth bags and incubated for 4 months at room temperature.

Results and Discussion

Results indicated that there were highly significant differences between varieties in terms of adult emergence. Adult emergence from RAZ 2 after 4 months was insignificant (Table 1).

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

Bean Variety	Total number of adults emerged[a]	% bean damage[b]
K 20	1029.8 (6.94)[a]	16.4 (0.41)[b]
RAZ 2	9.6 (2.26)	0.0 (0.00)
White haricot	1173.6 (7.06)	16.0 (0.37)
EMP 175	740.0 (6.60	4.4 (0.20)

Parentheses signify log and arsine ..... 100 transformations respectively.
[a]-Means in parentheses are log transformation
[b]-Means in parentheses are arsine ... 100 transformation.

Results confirm that RAZ 2 is highly resistant to *Z. subfasciatus* and the degree of resistance was consistent with previous laboratory assessments by Cardona *et al.*, (1990). The level of resistance in RAZ 2 therefore provides an adequate level of crop protection against *Z. subfasciatus* and is therefore recommended for use in situations where conventional pest control procedures cannot be utilized. This variety can also be used to incorporate resistance in other adapted varieties.

C. SOLAR HEAT DISINFESTATION OF BEANS

Materials and Methods

Beans (K 20) were infested with 40 pairs of *A. obtectus* twice. First infestation (incubated for 20 days) and all insects removed and second infestation (incubation for 7 days) and no adult removed. Treatments were: T1 open tray and T2 (top tray was covered with clear polyethylene and bottom with black polyethylene sheet).

Trays were placed in the sun and at one hourly interval seed temperature was taken. Thereafter counts made of total number of live/dead adults and at weekly interval adult counts were made for 5 weeks.

Results and Discussion

Temperatures of 64° and 65°C were recorded in T2 treatment while the highest recorded temperature in T1 was 45.5°C. All the adults in T1 escaped within the hour while 90.2% (Table 2) died in T2 and only 5.6% mortality was recorded in the control (T0).

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

Treatment	T0 (control)	T1	T2
% adult mortality	5.5	01	90
% escapes	0	100	0

Mean adult emergence in T1 and T2 were 16.7 and 15.8% respectively and 100% in control after 5 weeks incubation. 1 All insects escaped.

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

D. BEAN SIEVING, A CONTROL METHOD FOR *A. OBTECTUS*

The effect of sequenced sieving of beans were investigated in beans variety K 20 infested with *A. obtectus*. The sieving was done at seven days interval for a period of 49 days.

Results and Discussion

The effect of the various treatments are presented in Table 3.

Table 3. The effect of bean sieving on bean damage at two pre- and four post- treatment storage durations

Post-treatment storage period (days)	Percent damaged beans	
	Non-sieved	Sieved
Initial light infestation of stored beans (no pre-storage)		
0	0.00 d	0.00 d
50	0.40 d	0.02 d
110	7.67 cd	0.2 d
170	60.40 b	0.05 d
Initial heavily infested stored beans (50 days' pre-storage)		
0	9.26 cd	8.75 cd
50	62.70 b	13.62 c
110	69.67 b	13.47 c
170	88.80 a	13.57 c

Percent mean followed by a common letter are not different at P=0.05 determined by Duncan's multiple range test.

The results demonstrated that the sieving regime gives a good control of *A. obtectus* irrespective of duration of storage and of previous infestation. Very high damage increases were recorded in the non sieved beans. The results suggest that repeated sieving of beans, if adopted, can drastically reduce damage levels by *A. obtectus*. The method would be ideal for subsistence farmers where trays are already used for drying.

Sequenced bean sieving would be more successful under conditions where eggs are laid loosely in the grains as in *A. obtectus* infestation where the adults live outside the grains and the biology of the pest is accurately known. Even where such a criteria is not absolutely met a certain amount of damage could be avoided by simply sieving at regular intervals to reduce adult bruchids. The method combined with appropriate solar disinfestation could considerably extend storage durations by reducing rate of bean damage by *A. obtectus*.

E. ON-FARM BRUCHID CONTROL TRIAL

Materials and Methods

Bean, variety K 20 (Nambale) used during the study were bought from peasant farmers in Matuga Division, Mpigi District located in the central region of Uganda. The region experiences cool to mild climate throughout the year. Naturally-infested beans were bought immediately after being harvested, threshed and winnowed. They were bulked and divided into 40 sampling units (lots of 10 kg each). The lots represented three treatments and controls and each treatment was replicated two times. Five replicate farmers were selected randomly from Kawempe Division, Kampala District, also located in the central region. The selected farmers were from a group of farmers involved in the varietal demonstration trials with CIAT Regional and National bean programme. Each farmer was given 8 x 10 kg of beans contained in gunny bags. The beans were kept indoors and stored on raised platforms to avoid moisture which could easily lead to the rotting of the beans. The treatment methods were sunning, sieving, corn oil and the controls, and were replicated twice in each farm.

(i) *Sunning method*

The method involved putting the beans out in the sun once every week to dry by the farmers. The beans were spread on mats made out of palm leaves. The bags used in storing the beans were also spread out in the sun. The beans were on each occasion exposed in the sun for at least 6 hours. Sunning was continued for five weeks.

(ii) *Sieving method*

Hand-held wire mesh trays measuring 1 m wide by 2 m long, and fitted with sieves of mesh size 5 x 5mm was used. Sieving was done once every week by the farmer and the investigator, each holding one end of the sieve. Each lot was sieved for at least 5 minutes. Foreign matter and any other debris which got screened out were not put back in the bag. Sieving was continued for 5 weeks.

(iii) *Corn oil method*

Corn oil was bought from the open market. It was applied to the beans at the rate of 5 ml/kg, and mixing was done physically. The oil was applied only once on the day the beans were taken to the farmers.

iv) *Controls*

The controls represented bean lots which were not subjected to any kind of treatment till the time of data collection.

On the 49th day after the beans had been with the farmers, the beans were brought out for data collection. The parameters taken were:

(i) number of weeviled beans, and
(ii) number of emergence holes.

The total number of beans per lot was also taken.

Representative sample per replicate was obtained by bulking the 10 kg of beans and dividing it into four quartets of about 2.5 kg by conning and quarterly. Two diagonal quartets were bulked and sub-divided into four quarters of about 1.25 kg each. One quarters was selected randomly, and 500 g of beans was weighed out. This was used as reference source for data. After recording the data, the representative samples were put back into their respective bags.

Data collection was made after every 2 weeks, and this was repeated five times. The last data represented the 105th day (3½ months) the beans had been in storage.

Assumptions

1. It was generally assumed that the infesting bruchid species was *A. obtectus* (Silim, unpublished).
2. No artificial infestation was carried out, for *A. obtectus* infestation begins in the field and continues during storage (Silim, unpublished).
3. No initial count was taken since there was no evidence of adult emergence in any of the lots.

Data analysis

The data were analyzed as a randomized complete block design. The Duncan's multiple range test was used to determine if differences between treatment means were true, and how closely related the means were (Table 4).

Results and Discussion

Table 4. Comparison among treatments using mean percentage of weeviled beans.

Treatment method	Treatment means (%)				
	4 weeks	9 weeks	11 weeks	13 weeks	15 weeks
Sunning	3.15 a	3.23 a	2.94 a	2.76 a	3.64 a
Sieving	2.24a	2.33 a	2.64 a	2.93 a	4.10 a
Corn oil	5.68 ab	7.37 ab	12.76 b	14.67 b	8.19 bc
Controls	7.16 ab	11.43 b	21.06 c	25.44 c	37.67 d

Means followed by the same letters are not significantly different (Duncan's multiple range test, P 0.05).

During the entire storage period, sunning and sieving methods gave significantly reduced mean infestation than other methods (Table 4). Results from the corn oil method were intermediate. The effects of sunning and sieving on the reduction of *A. obtectus* population levels, were displayed differently however.

The reduction of infestation by sieving methods was due to the elimination of the loosely laid eggs by the newly emerged adults. Also, since sieving involves the agitation of beans, this could have upset the feeding behaviour of the larvae which led to delayed development and adult emergence, expressed by the small increases in population numbers for the entire period.

Corn oil treatment, though less effective than sieving and sunning, had a reducing effect on infestation and damage levels relative to the control. The use of oils in general has been reported with considerable success on those other bruchids which lay their eggs glued onto the seed coat (Messina and Renwick, 1983; Hill and Schoonhoven 1981; Schoonhoven 1978; Varma and Pandey, 1977; Khaire *et al.*, 1992). Oils can reduce oviposition by acting as ovicides, larvicides or as inhibitors to adult emergence (Messina and Renwick, 1983; Dohorey *et al.*, 1988). However, there must be proper and uniform coating of seeds and the residual activity must be prolonged.

The positive effect of corn oil treatment on *A. obtectus* during the first 77 days of storage was probably due to the reduced adult emergence, many having suffocated during the initial treatment or larvicidal effect. But as the storage duration was prolonged and the residual activity of the oil reduced due to its absorption by beans or the gunny bags used in storing treated beans. Adults which emerged or eggs which hatched were unaffected by the sub-lethal dosage of the oil. This calls for the testing of alternate containers, which have minimal oil absorption capability, which maintains the required lethal dosage level, repeated applications or increased dosages. Increase of dosages of oils has, however, to be treated with care as these decay with time and this results in the development of seed rancidity or reduced viability. The controls gave significantly higher mean percentage of infestation levels than any other treatments. This possibly reflected the amount of damage which can be caused to stored produce by *A. obtectus* if not protected.

F. OTHER CONTROL METHOD

Other control methods currently being investigated include the use of botanicals such as *Gynandra gynadropsis*, *Melia azederach*, shea butter oil and others.

G. INVESTIGATION ON ALTERNATE HOST PLANTS OF *A. OBTECTUS*

Materials and Methods

Suspect host seeds were collected countrywide, these include *Macroptilium atropurpureus*, *M. latyrodes*, *Lablab purpureus*, *L. niger*, *Centrosema pubescens*, *Crotalaria incarna*, *Cajanus cajan*, *Vigna unguiculata*, *Cassia spectabilis*, *C. tora*, *C. gradis*, *C. petersiana*, *Desmodium lassiocapum*, *Bahinia punctate*, *Leuceana leucocephala*, *Caesalpina pulcherima*, *Piliostigma thorinigii*, *Acacia elator*, *Rychosia. Glycine favanica*, *tapary*, and two yet unidentified legume species. The legume seeds were allowed to incubate for one month and insect emergence noted and thereafter disinfected. Seeds were then infested with eggs of *A. obtectus* and allowed to incubate until adult emergence.

Results and Discussion

In most of the seeds the larvae died soon after penetration. In two legume species *M. atropurpureus* and *M. latyrodes* there was larval development but due to the small size of the seeds, food supply within the seed was exhausted within 28 days and most larvae/pupae therefore died. Few adults emerged but were of very small sizes and died soon after emergence. Complete development of the insects and adult emergence was noted in *C. cajan*, *V. unguiculata*, tapary beans and the two unidentified pea species. Alternate host plants of *A. obtectus* were therefore found to be legume species already domesticated by man.

H. A METHOD OF SEXING *A. OBTECTUS*

Materials and Methods

The significance of the hues, density and patterns of bristles on the pygidium of *A. obtectus* adults was investigated. These were classified into two variations. Variation 1: adult populations having brown pygidium were separated from variation 2, populations with brown and grey patterns on the pygidium. The two groups were sexed using the male genitalia (Table 5).

Results and Discussion

The results of the dissection indicate that the variations in the hues and patterns of coloration on the pygidium present a clearer form of sexual dimorphism for easier sexing of *A. obtectus*. Variation 1 is composed of males and variation 2 females (Table 5).

Table 5. Sex of insect populations for each of the pygidium variations.

Worker	Insects with variation 1		Insects with variation 2	
	Males	Females	Males	Females
1	33	2	2	62
2	54	1	0	45
3	49	0	0	51
4	49	2	1	48
Total	185	5	3	179
% Composition	97.35	2.6	1.4	98.57

I. Travelling workshop and survey

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

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DISCUSSION

Nderitu	:	You showed bruchid infestation in the field, how much loss do you have in the field and should control measures be taken ?
Nahdy	:	Loss in the field is critical. Overall loss is 5-15% depending on length of storage.
Agona	:	35% loss has been observed in 105 days during a laboratory study.
Giga	:	The pungent smell associated with *Acanthoscelides* infestation means zero market value.
Nderitu	:	Do storage methods vary with the amount of seed harvested ? What are the loss figures associated with bruchid damage in Ugandan local varieties?
Ampofo	:	In some instances farmers sell their produce soon after harvest to avoid storage losses.

BREEDING BEANS FOR BRUCHID RESISTANCE IN TANZANIA[1]

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INTRODUCTION

The Bean Improvement Programme at Sokoine University of Agriculture (SUA) has since 1992 embarked on breeding beans which are resistant to the important bean bruchids namely *Zabrotes subfasciatus* and *Acanthoscelides obtectus*. The programme is basically incorporating "arcelin", a protein which is known to confer resistance to *Zabrotes subfasciatus* (Osborn, *et al.*, 1987), into five most promising bean lines developed at SUA. On the other hand the programme is seeking possible sources of bean bruchid resistance in bean landraces collected from within the country as well as from introductions. Furthermore the programme is establishing the relative importance of bean growing regions of Tanzania.

MATERIALS AND METHODS

Arcelin was introduced in the following five lines by crossing each one of them with a bean line RAZ-24-2 obtained from CIAT as a source of arcelin.

(1) SUA 90
(2) EP 3-2
(3) EP 4-4
(4) C12-2/216-7-8
(5) C11-1/216-2-6-2

The standard backcross method was used in back crossing the F_1 three times to their respective parents so as to recover the parental genetic potential in the crosses. These crosses are now being selfed three times and at each stage of selfing, the resulting seeds will be subjected to bruchid feeding trials in order to identify plants which are homozygous for the presence of arcelin.

In searching for other sources of bean bruchid resistance a total of 132 landraces and 122 introductions have been collected. The landraces were collected from six major bean growing regions in the northern and southern parts of Tanzania. The introductions were mostly obtained from CIAT. During the 1992/93 season, seeds of each landrace/introduction were planted in a single row 5 m long at a spacing of 60 cm between the rows and 20 cm within the row. Seeds of the same age have now been harvested and will now be subjected to bruchid feeding trials involving *Zabrotes subfasciatus* and *Acanthoscelides obtectus* separately. From these trials, bean landraces/introductions showing significant resistance to one or both bruchid species will be identified for further breeding work as parents possessing bruchid resistance in the bean improvement programme. Permanent sources of both *A. obtectus* and *Z. subfasciatus* have been established and are being maintained separately in the lab at a temperature 28°C

[1]This paper was not discussed in detail as the author did not attend the meeting.

and 80% R.H. for *Z. subfasciatus* and 25°C and 80% R.H. for *A. obtectus* respectively as recommended by CIAT. These colonies will be used in the evaluation of bean materials for bruchid resistance.

In the attempt to identify bean bruchid species and therefore establish the relative importance of the two major bruchid species, beans infested by bruchids were collected from the major bean growing regions in Tanzania as mentioned above. These were placed in plastic bottles and labelled accordingly: 6 weeks later the bruchids were separated from the beans by slicing, and passing through a 3 - 4 mm mesh and finally identified taxonomically under a microscope. Bruchids belonging to one species in each sample were separated and counted. The percentage of each species in a sample was computed.

RESULTS AND DISCUSSION

Results for this study are underway. However, it has been observed that *A. obtectus* seems to be no longer confined in the cooler areas only - but is found in most areas where beans are being grown.

CONCLUSION

Work on collection of landraces and bruchids for identification is still going on in the western part of Tanzania. Moreover collection of introductions is also still in progress.

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INTEGRATED CONTROL OF BEAN STEM MAGGOT (BSM) FOR LOW EXTERNAL INPUT FARMERS

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1. INTRODUCTION

Research on Bean Stem Maggot (BSM) has been carried out at Lichinga, Niassa Province, in the north of Mozambique with the aim of understanding the phenology and importance of the pest. The objective of the study has been to develop an integrated control programme for farmers in the region who have very limited access to external inputs (insecticides, fertilizer etc.).

2. SUMMARY OF RESULTS AT LICHINGA

2.1. Phenology of BSM.

The principal species of BSM on the plateau in Niassa is *Ophiomyia spencerella* (normally 90% or more of pupae sampled) with a smaller percentage of *O. phaseoli* (typically 10% or less of sampled pupae) and *O. centrosematis* (less than 1%).

Levels of infestation of BSM on beans vary with date of sowing during the main cropping season (November-June) but are similar across seasons. In two local varieties (manteiga, encarnado) infestation is low at the start of each planting season (1st planting season early to mid December, 2nd season early to mid March) and rises with delay in sowing (Figure 1), especially in the first planting season. Rates of infestation have been linked significantly to the percentage parasitism by the parasitoid *Eucoloidea impartus* in the preceding generation (Figure 2). There is a tendency (not statistically significant) for infestation to rise with increase in rainfall in the month of sowing (Figure 3).

Figure 1. Numbers of BSM/10 plants 30 DAE over five seasons, 1988-1993, in the local bean varieties Encarnado and Manteiga.

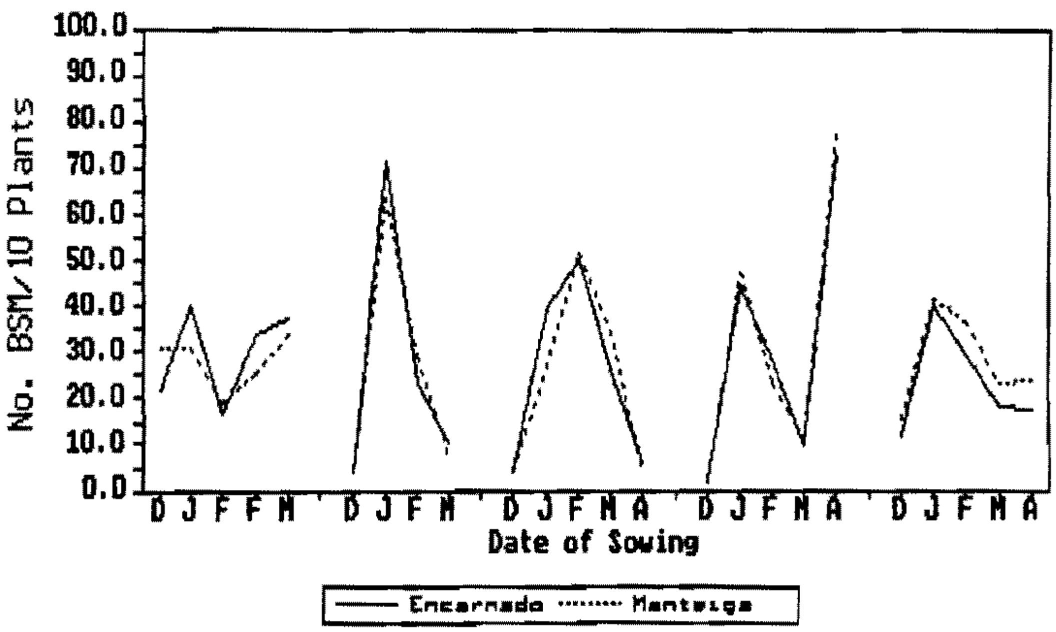


Figure 2. Number of BSM/10 plants with percentage parasitism of *E. impartus* in the previous generation.

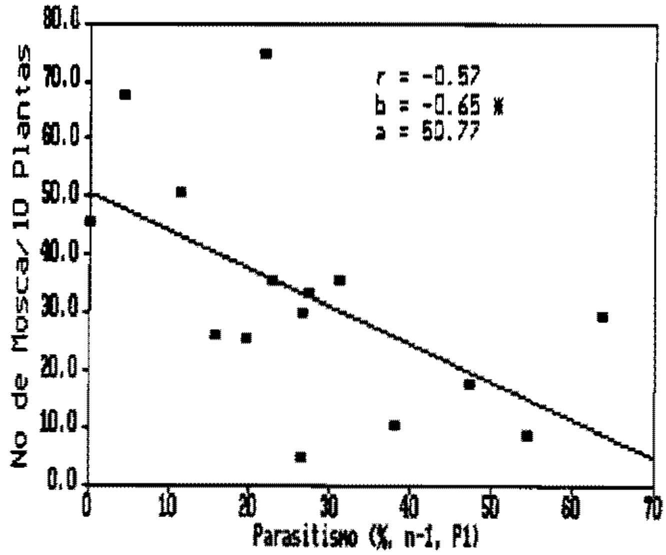
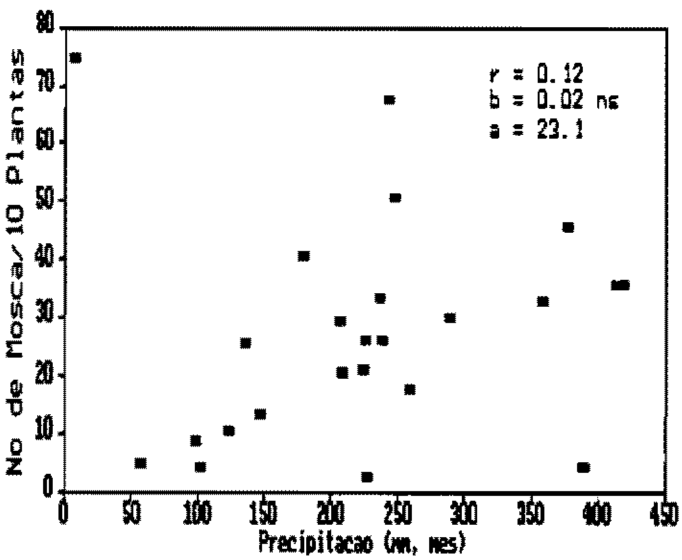


Figure 3. Number of BSM/10 plants with precipitation (mm) in month of sowing.



Peak emergence for BSM adults is 42 days after crop emergence (DAE) and for parasites 48-58 dae. Apart from *E. impartus*, the parasitoid *Opius melanagromyzidae* was found parasitizing BSM in significant numbers, and is possibly the reason for low numbers of *O. phaseoli* as it seems to be more efficient at parasitizing this species.

BSM infestation is low in off-season beans sown in "baixas" (wet valley bottoms with residual moisture), but it is considered probable that these plantings are responsible for carry over between seasons, as no viable pupae have been found in bean residues, or emergence of adult BSM observed later than 60 dae in sampled pupae.

2.2 Importance of BSM

Percentage plant loss during the growing season and final yield of dry grain (not always the objective of the farmer) have been significantly linked to BSM infestation (Figures 4 and 5 for example) though it has been more difficult to attribute the causes directly to BSM. The form of the yield response curve suggests that there are aggravating factors including a general weakening of the plants and the entry of root rots into the wounds caused by BSM which rapidly increase yield loss even with a small increase in infestation.

Figure 4. Yield (kg/ha) with number BSM/10 plants, variety Encarnado.

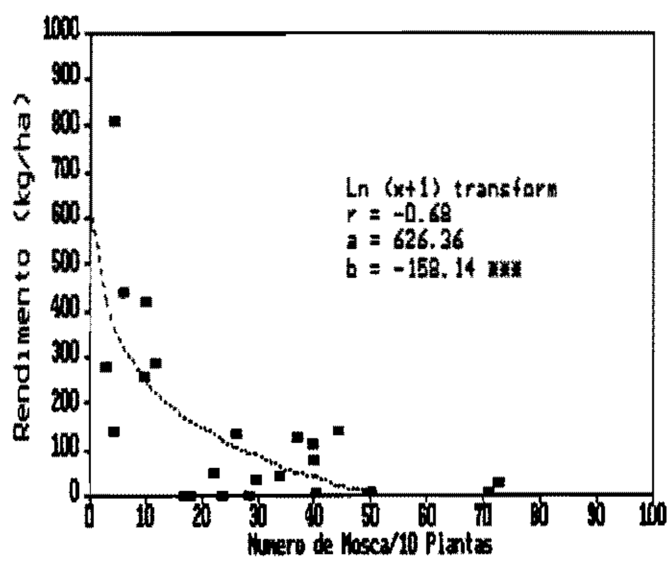
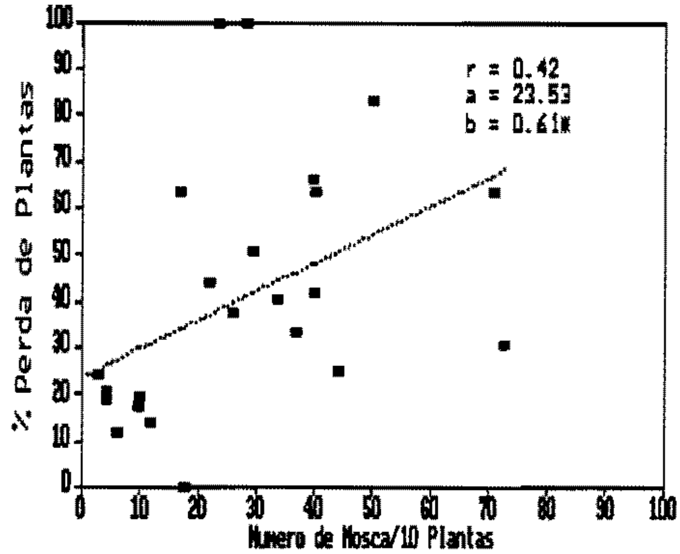


Figure 5. Percentage plant loss with number of BSM/10 plants, variety Encarnado.



On average about 18.0% more plants are harvested in treated (BSM absent) over untreated (BSM present) plots and there is a yield advantage of about 15.5% over the five seasons with treated plots. An increase of one BSM per plant (or 10 BSM/10 plants) leads to 7.4% more plant loss and 12.5% less yield (Figures 6 and 7).

Figure 6. Percentage difference in plant loss with difference in number of BSM/10 plants.

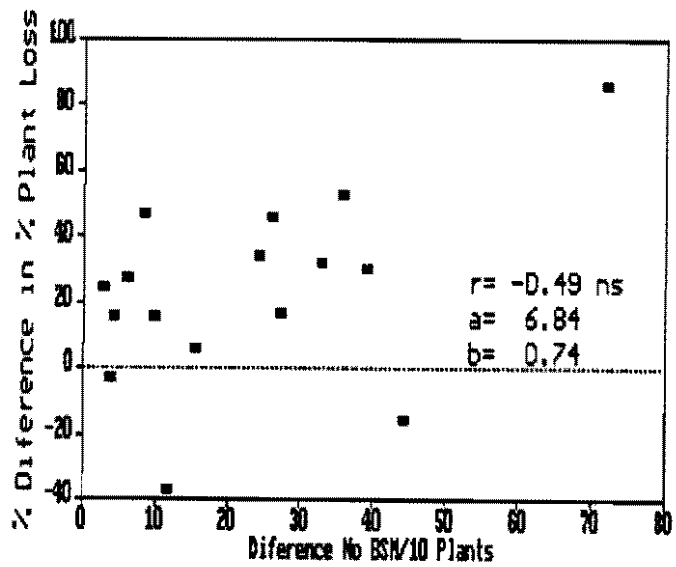
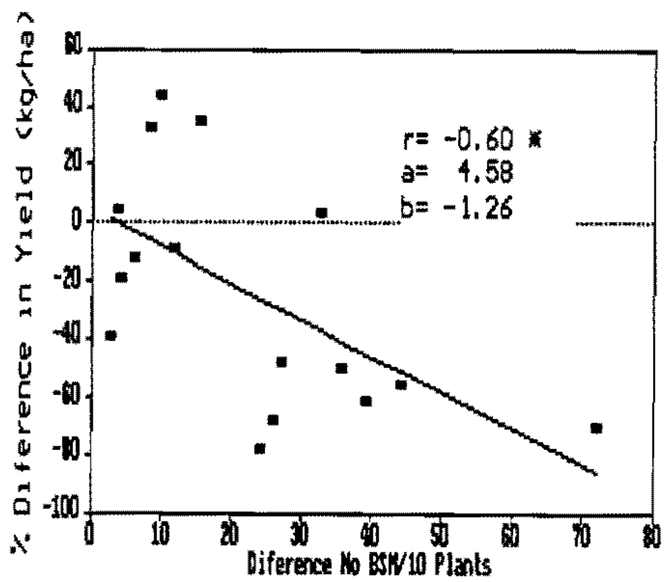


Figure 7. Percentage difference in yield (kg/ha) with difference in number of BSM/10 plants.



2.3. Control with insecticides

Control of BSM has proved possible with a range of insecticides and application methods. Cipermethrin (20 ec 1 ml/lt) applied as a foliar spray 2, 7 and 14 dae, diazinon (60 ec 2 ml/kg) as a seed treatment and endosulfan (50 ec 5 ml/kg) as a seed treatment have all proved effective though endosulfan provides the most consistent protection against BSM throughout the season. With the small yield advantage associated with treated beans (15.5%) it is doubtful that the use of insecticides is economic at the present given the low overall yields (average of 150 kg/ha over five seasons at all sowing dates).

2.4. Resistant varieties

It appears that some varieties are partially resistant or tolerant to BSM. In Niassa three varieties have proved promising in this respect, including Ikinimba and ICA Pijão from the CIAT Bean Stem Maggot Resistance Nursery and A 417, a CIAT line from Brazil. It is hoped that these varieties may be included in future bean improvement programmes.

3. INTEGRATED CONTROL OF BSM

Drawing from work elsewhere, and on the basis of the results and observations in Niassa, it has been possible to make recommendations for an integrated control programme against the BSM. It must be borne in mind however that there are other limiting factors to production, especially soil fertility, which need to be addressed for yields to increase significantly for the subsistence farmer.

Emphasis here is given on recommendations for cultural control of BSM which cost the farmer less and include:

1. Sow beans as early as possible in each sowing season (early December and early March in Niassa) to avoid periods of high infestation. Try to sow beans concurrently in any given area.

2. Observe good cultivation practices (prepare soil well, sow on ridges, fertilize at the optimum rate and on time) to ensure uniform emergence of seedlings. It is known that healthy plants are less affected by infestation of BSM and root rots.

3. Earth up the plants 20-30 DAE to encourage adventitious root formations.

4. Bury (or destroy) the remains of the previous crop and try to leave an interval as long as possible between planting seasons, as compatible with good crop husbandry (in the second planting season beans can suffer moisture stress if planted late).

5. Refrain from applying insecticide to the crop (or intercrop) between 40 and 70 dae, the main period of parasite emergence.

6. If infestation is expected to be high (late sowing in any planting season) treat the seed with endosulfan (50 ec 5 g/kg) or diazinon (60 ec 2 ml/kg) before sowing. It is best to avoid foliar applications of insecticide against BSM.

DISCUSSION

Nyirenda : Ridging up may increase termite attack ?

Davies : We have had no problems with termites as of yet.

DEVELOPMENT AND IMPLEMENTATION OF AN INTEGRATED PEST MANAGEMENT PACKAGE FOR SNAP BEANS PRODUCTION IN KENYA

John Nderitu
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SUMMARY

Survey on pests, diseases and their control strategy has been carried out at Mwea-Tebere area, Kirinyaga District. There is the problem of excessive use and misuse of insecticides in the area. French beans are being grown by small scale farmers who would greatly benefit from use of an IPM strategy to better manage the pests. The area will be used as an experimental site to develop IPM technology, IPM implementation trials and participatory research. The total cost of all the research activities will be US$ 89,210 for a period of 3 years.

INTRODUCTION

French beans (snap beans) is one of the major horticultural export crops in Kenya. In 1991 and 1992 a total of 15000 tons was exported to Europe each year (Anon, 1993). The main growing areas in the country are Thika, Athi River, Mwea-Tebere and Naivasha.

A pilot survey on the pests and current control measures of major pests of French bean was carried out at Mwea-Tebere area (Nderitu, 1993). French bean farming started in the area in 1982. There are 250 hectares under French beans with a production of 1500 tonnes. There are about 1000 French bean farmers with an average of 0.2 ha under beans. The French beans are grown under rainfed conditions during the long and short rains and under irrigation during dry periods. The survey identified the problem of excessive use and misuse of pesticides in the area. Therefore, a project is proposed to develop sustainable integrated pest management package that will reduce the use of insecticides in French bean production and increase the quality (lower insecticide residues) of the produce. The project will develop integrated pest management strategy at the pilot area which would be modified and used on dry beans and in other French bean growing areas in the country. Thus, the overall objective is to develop an integrated pest management package that is sustainable and compatible with current French bean crop management, and at the same time seek to reduce insecticides use and subsequent reduction of insecticide residues on the net produce.

SPECIFIC OBJECTIVES

1. To determine the insect pest complex and natural enemies on a French bean crop.
2. To study the population dynamics and damage of key pests on French beans.
3. To study the population dynamics of the parasites/predators of the key pests on French bean and their levels of predation/parasitism.
4. To determine yield losses due to key pests on French beans.
5. To establish the action thresholds for key pests on French bean crop.
6. To evaluate current control practices (i.e. efficacy of insecticides) on French beans.

7. To evaluate methods to reduce fungicides use.
8. To evaluate different chemical control strategies for pests and diseases.
9. To evaluate alternate control methods of insect pest on French beans, i.e., biological, cultural.
10. To compare different pest management strategies on French beans.
11. To set on-farm trials to validate IPM alternatives.
12. To evaluate integrated pest management packages in small farmers fields through participatory research and transfer the results using the available extension services.

MATERIALS AND METHODS

A. Field Monitoring of Insect Pests of Snap Beans and Their Natural Enemies

The commercial French bean variety (Monel) will be grown in small plots of 5 x 5 m replicated four times. The path between plots and blocks will be 2m. The plots will be paired, with one treated according to the farmers traditional management practice and the other no pest management practice. Data will be taken weekly on each plot as follows:

1. (a) The number of bean stem maggot punctures after plant emergence upto 4 weeks old plants.
   (b) The number of dead plants after plant emergence.
   (c) The number of bean stem maggot and pupae per 20 bean plants at 4 weeks after plant emergence.
2. The number of bean aphids will be scored on the following scale:

   1 = No aphids present
   2 = <50 individual aphids/plant
   3 = 50 - 100 individual aphids/plant
   4 = > 100 individual aphids/plant

3. Whole bean plants (20/plot) will be sampled for:

   (i) visible live African bollworm larvae.
   (ii) bollworm damaged pods but with larvae no longer present at 8 weeks after plant emergence.

4. Whole bean plants 20 will be inspected for *Maruca testularis* and recorded at 8 weeks after plant emergence.
5. Whole bean plants 20 will be inspected for adult *Acanthomia* spp. and recorded at 8 weeks after plant emergence.
6. The damage by red spider mites will be recorded for the whole plant on the following scale:

   1 = No leaf damage due to mite feeding.
   2 = Slight damage - a few leaves showing slight symptoms of mite attack.
   3 = Moderate damage - many leaves showing moderate symptoms of mite attack.
   4 = Severe damage - the majority of leaves showing serious damage.

7. The number of whitefly nymphs on 3 leaves per plant taken at random on the top, middle and bottom part of twenty bean plants.

8. Three leaves will be sampled at random from each plant and the total number of larvae and mines of leaf miner (*Liriomyza trifolii*) will be counted from 20 plants.
9. Two flowers will be sampled at random from each bean plant and put into 70% alcohol. The total number of thrips on 20 bean plants will be counted and identified.
10. 10 sweeps will be taken per plot with a sweep net. The adult pests and their natural enemies complex will be recorded in each plot.
11. The yield in terms of pods/plant and quality of pods will be recorded.
12. All the costs of operation in the experimental site will be recorded. The price of produce will also be recorded.

B. The Yield Losses of French Beans Due to Key Pests

(i) *Assessment of yield losses of beans due to bean stem maggot infestation*

French beans will be planted in 8 plots of 5 x 5 m. Four plots will be treated with high level dose of carbofuran granules to completely control bean stem maggot for 4 weeks after plant germination. Whiteflies and red spider mites will be monitored during the growth of the crop. They will be controlled by dimethoate and Dicofol respectively. The thrips and *Acanthomia* bugs will be assessed during and after flowering and will be controlled by spraying permethrin. Benlate and Antracol fungicides will be used to control fungal diseases. The quality and quantity of French beans will be assessed.

(ii) *Assessment of yield losses due to whitefly infestation*

French beans will be planted in 8 plots of 5 x 5 m. Carbofuran granules will be used during planting for the control of bean stem maggots. The red spider mites will be monitored and controlled by Dicofol in four plots in the field. The thrips and *Acanthomia* spp. will be controlled by permethrin after flowering. Antracol and Benlate will be sprayed to control fungal diseases. The quantity and quality of French beans will be assessed from each of the eight plots.

(iii) *Assessment of yield losses due to red spider mites in the bean field*

Eight plots of 5 x 5 m of French beans will be planted in the field. Carbofuran granules will be applied during planting to control bean stem maggots in four plots in the field. Whiteflies will be controlled by Sumithion during the early growth period of the crop and the thrips and *Acanthomia* bugs will be controlled during and after flowering of the crop. Antracol and Benlate will be sprayed to control fungal diseases. The yield loss due to red spider mites will be assessed.

(iv) *Assessment of yield losses due to thrips/Acanthomia in the bean field*

French beans will be planted in 8 plots of 5 x 5 m. Carbofuran granules will be applied at planting time. Foliar insects will be assessed and dimethoate and Selecron will be applied during the first 4 weeks to control them. Antracol and Benlate will be applied to control fungal diseases. The loss in quality and quantity of French beans due to flowering and post flowering pests will be assessed.

C. Action Threshold of Major Pests of French Beans

The action thresholds of the major pests will be calculated using formulas by Stewart and Khattat (1980) and Ogunlana *et al.* (1974).

(i) *Action threshold of bean stem maggot, Ophiomyia spp. on French beans*

French beans will be planted in plots of 5 x 5 m. Treatments of five different dosages of carbofuran will be applied in the block and relocated four times. The treatments will be as follows:

1 = recommended rate of application
2 = 2x recommended rate
3 = 3x recommended rate
4 = 4x recommended rate
5 = farmer's rate
6 = Control (no application)

The number of ovipunctures/5 plants, number of dead plants, and number of larvae/pupae per 5 plants will be recorded in each plot. The experiment will be repeated for two seasons at the pilot areas. The recommended fungicides for control of fungal diseases will be sprayed in the experimental field. The costs of carbofuran and application, and value of fresh pods will be recorded.

(ii) *Action threshold of whiteflies on French bean*

The experiment will be conducted in a randomized complete block design with four replications. Each plot size will be 3 x 3 m and 2m between rows and blocks. The following insecticidal treatments will be made:

1 = 2 foliar sprays/week
2 = 1 foliar spray/week (farmer's practice)
3 = 1 foliar spray/2 weeks
4 = 1 foliar spray/4 weeks
5 = 1 foliar spray/6 weeks
6 = Control (no application).

Dimethoate will be used as the foliar treatment for control of whiteflies and carbofuran will be used during planting to control bean stem maggots. Red spider mites will be monitored and controlled with Dicofol. Flowering pests will be monitored and controlled with permethrin or Festac. Whitefly infestation in the plots will be assessed. The costs of dimethoate sprays will be recorded. The yields of green bean pods and their sale price will be recorded.

(iii) *Action thresholds of red spider mites, Tetranychus spp. on French beans*

French beans will be planted in plots of 3 x 3 m in a randomized complete block design with four replication of each treatment. There will be six treatments as follows:

1 = 2 foliar sprays/week
2 = 1 foliar spray/week (farmer's practice)
3 = 1 foliar spray/2 weeks
4 = 1 foliar spray/4 weeks
5 = 1 foliar spray/6 weeks
6 = Control (no application).

Dicofol will be used at different levels as foliar treatments for red spider mites. Carbofuran granules will be used during planting to control bean stem maggots. Endosulfan will be used to control whiteflies and permethrin to control thrips and *Acanthomia*. The red spider mites in the bean plots will be recorded. The yields of the French green pods and sale price of pods will be recorded.

(iv) *Action thresholds of thrips and Acanthomia spp. on French beans*

French beans will be planted in plots of 3 x 3 m. Six treatments will be replicated four times in randomized complete block design. The paths between plots and blocks will be two metres. Carbofuran granules will be applied during planting to control bean stem maggots. Foliar pests will be monitored and dimethoate and Dicofol will be used during the early stage of growth of the plants and before flowering. During and after flowering the six treatments will be applied as follows:

1 = 2 foliar sprays/week
2 = 1 foliar spray/week (farmer's practice)
3 = 1 foliar spray/3 weeks
4 = 1 foliar spray/4 weeks
5 = 1 foliar spray/6 weeks
6 = Control (no application).

Permethrin or Fensac will be used of the treatments in the field. Thrips and *Acanthomia* spp. will be assessed in the field. Fungicides will be applied in the plots to control fungal diseases. The costs of the permethrin/Fensac spray and the value of the fresh green pods per kg will be recorded. The yield of pods will be recorded after every harvest.

D. Preliminary Screening of Insecticides for Control of Major Pests and Conservation of Predators/Parasites on French Beans

Beans will be grown in plots of 3 x 3 m in a randomized complete block design. The plots will be replicated four times, with a path of 2 m between rows and between plots. Ten insecticide treatments used by farmers in the pilot area will be tested in addition to new insecticide products in the market. Each chemical will be applied four times per season, except seed treatment or pre-planting treatment done before planting. Four foliar treatments will be done 2, 4, 6, 8 weeks after plant emergence. Before and after each spray, the major pests of French beans will be scored or counted per plot. The yield of green pods per plot will be assessed.

E. Testing Pesticide Package for Control of Major Pests on French Beans

French beans will be planted in plots of 3 x 3 m. The treatments will be replicated four times in a randomized complete block design. The path between plots and blocks will be 2 m. Four treatments will be applied on the bean plots as follows:

1 = Seed treatment/soil insecticide + systemic (OP + SP)
2 = Seed treatment/soil insecticide + systemic miticide OP (Selecron) + SP
3 = Seed treatment/soil insecticide + SP
4 = Seed treatment/soil insecticide + OP
5 = No treatment.

The combination of each treatment will be decided after experiment 4 is done. Each treatment will be applied 3 times in the field. The first application will be pre-planting; the second 3 weeks after plant emergence and the third during flowering stage of the plants. Fungicide will be applied to control diseases. The pest infestation levels will be assessed. The yield of French beans will be recorded.

F. Establishment of Effective Number of Sprays of Insecticides in a Bean Crop

French beans will be planted in plots of 3 x 3 m in a randomized complete block design. Seven treatments will be replicated four times. The path between plots and between blocks will be 2 m. Bean seeds which are insecticide-treated will be used. Carbofuran will be applied during planting. The most effective organophosphorus insecticide (OP) foliar and synthetic pyrethroid (SP) insecticide spray noted in experiment E will be applied as follows:

1 = Seed dressing/soil insecticide + 1 OP spray + 1 SP spray
2 = Seed dressing/soil insecticide + 2 OP spray + 2 SP sprays
3 = Seed dressing/soil insecticide + 3 OP spray + 3 SP spray
4 = Seed dressing/soil insecticide + 4 OP spray + 4 SP spray
5 = Seed dressing/soil insecticide + 5 OP spray + 5 SP spray
6 = Seed dressing/soil insecticide + 6 OP spray + 6 SP spray
7 = Control.

The organophosphorus insecticide sprays will be applied before flowering and the synthetic insecticide sprays will be applied during and after flowering. The crop will be treated with fungicides to control fungal diseases. The major pests on French beans will be assessed. The yield of green pods will be recorded after each harvest. The costs of insecticide treatments and value of produce will be recorded. The natural enemies complex of major pests on the treated and untreated beans will be recorded.

G. Cultural Control of Bean Stem Maggots

French beans will be grown at the pilot area in plots of 5 x 5 m in a randomized complete block design. Six treatments will be replicated four times. The following treatments will applied:

1 = Earthing-up of beans at 3 days after plant emergence (DAE)
2 = Earthing-up at 1 week after plant emergence (WAE)
3 = Earthing-up at 2 WAE
4 = Earthing-up at 3 WAE
5 = Earthing-up at 45 WAE
6 = Earthing-up at 5 WAE
7 = Carbofuran application at planting.

The mortality of bean plants, number of larvae/pupae in stems will be counted. The number of French green pod and their quality will be recorded.

H. Comparison of Integrated Pest Management (IPM) and Traditional Management (TM) of Pests, Natural Enemies and Yield on French Beans

French beans will be grown in two farmers' fields and research station site at the pilot area. The beans will be in plots of 10 x 10 m. The following three treatments will be applied:

1 = "Chemical" - judicious use of insecticides; application at recommended action levels.
2 = Traditional management (TM) - Farmers' preventative application of insecticides.
3 = IPM - package developed in experiment A - G.

The treatments will be in randomized complete block design, replicated four times. The path between plots and blocks will be 2 m. Samples will be collected once a week to assess the pests/predator/parasite infestation and damage levels. The costs of application of each treatment will be recorded. The marketable fresh green pods will be weighed and the monetary value recorded.

I. Evaluation of Integrated Pest Management Package on Farmers' Field

IPM and farmers' package will be tested on two farmers' fields. The plot sizes will be 20 x 20 m. They will be replicated four times. The effectiveness of each package will be assessed by sampling the pests on the crop. The yield of the French beans in terms of marketable fresh green pods and quality of pods will be assessed. The cost of each management package will be recorded.

J. Integrated Management of Pests on Snap Beans at Pilot Area

An experimental site of 0.5 ha will be planted to French beans. In one half of the field, IPM package will be applied. The other half of the field will be sprayed according to a normal, calendar-based traditional management practice of the farmers in the area. Plots will be monitored each week to assess disease and insect pests levels. Yield will be assessed by removing pods and the marketable ones counted and weighed. They will be marketed and the value recorded. The cost of application of the control strategy will be recorded.

K. Output

(a) Recommendations on integrated management of major pests of French beans.
(b) Develop pest control technologies that are safe, sustainable and cost-effective to the French bean farmers.

L. Inputs

(a) Motorcycle
(b) Travel and accommodation expenses
(c) Technical assistants and casual labourers
(d) Farm inputs
(e) Interlinkages and collaborators - National Horticultural Research Centre, CIAT, National Extension, Service, National Fibre Research Centre (Kirinyaga), Farmers.

M. Workplan

	Activities	Duration (year)		
		1993	1994	1995
1.	Determination of insect pest/natural enemies complex	X		
2.	Studies on population dynamics of key pest/natural enemies	X	X	
3.	Determination of yield losses	X	X	
4.	Establish action thresholds	X	X	
5.	Comparison of different management strategies		X	X
6.	Participatory IPM research		X	X
7.	Data processing	X	X	X
8.	Report writing	X	X	X
9.	Attend conferences	X	X	X
10.	Practical attachment (1) week	X	X	

N. Budget

	Description	Year 1 (US $)	Year 2 (US $)	Year 3 (US $)
1.	Cost motorcycle	4000	-	-
2.	Transport operations	1500	1500	1500
3.	Local travel and accommodation	2000	2000	2000
4.	Purchase of laboratory equipments	3000	2000	1000
5.	Farm inputs	2000	2000	2000
6.	Office supplies and services	1500	1500	1500
7.	Technical field workshops	-	3000	3000
8.	International travel	3500	3500	3500
9.	Salaries and allowances:			
	(a) Research assistants	5000	5000	5000
	(b) Technician	2200	2400	2600
	(c) Temporary labour	2000	2400	3000
10.	Cost of computer	4000	2530	2510
11.	Overhead (10%)	3070	-	-
	Total	33,770	27,830	27,610

Total grant for 3 years = 89,210 US$

O. Report writing and dissemination of results.

1. Reports to the donor
2. Publications - 4 papers for the scientific journal
3. Seminars - to give 2 seminars
4. Conference - attend 2 conferences

P. References

Anonymous (1993). Horticultural Crops Development Authority Report.

Nderitu J.H. (1993). Survey on the pests and current control measures of major pests of French beans in Mwea-Tebere area, Kirinyaga District. 3rd Eastern Africa Bean Research Conference 19th - 23rd April, 1993, Thika, Kenya.

Ogunlana M.O. and Pedigo L. P. (1974). Economic-injury levels of the potato leaf hopper on soybeans in Iowa. J. Econ. Entomol. 67 (1): 29-32.

Stewart R.K. and Khattat A.R. (1980). Pest status and economic thresholds of the tarnished plant bug, *Lygus lineolaris* (Hemiptera: Miridae) on green beans in Quebec. Can. Int. 112: 301-305.

Q. Project Logic Framework Summary

	Narrative Summary Project Goal	Verifiable indicators	Means of verification	Important assumption
1.	**Project Goal:**			
	Evolve an integrated pest control for the French bean farmers.	Quality and Quantity of French beans for export.	Increased French bean production. High quality French beans.	Well organized extension service for French bean farmers. Farmers will accept the control methods.
2.	**Project Objectives:**			
	a. To describe pests of snap bean.	Major pests of French beans and their control identified.	Report on major pests and control methods of French beans.	Transport and funds available.
	b. To evaluate pesticide in French bean production.	Effective chemicals for control of French bean pests.	Effective chemicals for IPM package.	Farmers are ready to use the recommended chemicals to increase the quality and quantity of beans.
	c. To develop an integrated pest management strategy for the control of major French beans pests.	IPM package	Effective control of bean pests.	Farmers adopt the IPM package.
	d. To evaluate the integrated pest management package under varying conditions.	Effective IPM package.	Effective control of beans.	Farmers adopt the IPM package.

DISCUSSION

Mutimba : The transit seems to be to target spraying regimes ? Have you got definite suggestions for IPM ?

Nderitu : No, not yet, maybe after 3 years.

Nyirenda : Fifteen sprays per cropping cycle are quite high and with pyrethroids there could the induction of whitefly and red spider mite resistance.

INTEGRATED PEST MANAGEMENT (IPM) DEVELOPMENT AND PRACTICE IN MAURITIUS

Afzale Rajabalee
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INTRODUCTION

Mauritius is situated 750 km east of Madagascar. It covers an area of about 186,500 ha, of which approximately 100,000 ha is under cultivation. For more than three centuries, the economy of Mauritius has remained dependent on sugar cane, which occupies nearly 90% of the cultivated land. In a vigorous attempt to reduce unemployment and solve the foreign exchange problems facing the country, Mauritius has since the early seventies, embarked upon a plan to diversify its economy in key sectors such as industry and tourism. In the agricultural sector, a diversification project was initiated through extensive production of potatoes, maize and groundnut in between rows of sugar cane or in rotation between two crop cycles. Widespread cultivation of new high yielding varieties over large areas provided a better environment to pests and better economic returns. The implementation of IPM programmes was a logical follow-up to intense agricultural diversification. IPM is not a new concept but its widespread application has become necessary because of injudicious use of pesticides. However, the benefits go even further, considering the economic and social aspects and even more so, for developing countries where foreign exchange and workmen's safety are key issues.

CONTROL OF SUGAR CANE PESTS

Major insects attacking sugar cane in Mauritius comprise borers, scale insects and white grubs. They are all controlled biologically. A typical example is the spotted borer *Chilo sacchariphagus*, which is a chronic pest kept below economic levels through the action of a multitude of natural enemies, (Williams, 1978) some of which are:

1. *Trichogramma* sp. (egg parasite)
2. *Apanteles flavipes* (larval parasite)
3. *Trichospilus diatraeae* (pupal parasite)
4. *Xanthopimpla stemmator* (pupal parasite)

Number of parasites associated with some key pests of sugarcane are shown in Table 1.

Table 1. Number of parasite species of major sugar cane pests.

Borers	
Chilo sacchariphagus	9
Sesamia calamistis	12
Scale insects	
Aulacaspis tegalensis	10
Pulvinaria iceryi	10
White grub	
Phyllophaga smithi	12

This control method, used in conjunction with good cultural practices and suitable varieties could also have been termed IPM, but for the fact that no insecticide is applied on sugar cane in Mauritius, except in very rare cases during occasional outbreaks of armyworms or locusts.

IMPORTANCE OF AGROCHEMICALS IN THE DIVERSIFICATION PLAN

With the agricultural diversification policy instituted in 1974, food crop production became a national priority. The country is now self sufficient in potatoes, but for economic reasons, maize and bean cultivation are less important. Snap beans are still being produced but only for the domestic market.

To attain high yields, there was a dramatic increase in the use of pesticides, especially, after the accidental introduction of the serpentine leaf miner *Liriomyza trifolii* in 1978. *L. trifolii* is a highly polyphagous pest attacking potatoes and beans (Dove, 1985). The insecticide which initially gave best control was methamidophos. However, acting against recommendations, growers, probably because of the efficacy of the product and the urge for quick monetary returns, made an abusive use of the chemical. A few years later, signs of insect resistance became apparent. On the other hand, consumers were becoming more and more conscious of pesticide pollution as the commercial involvement in this aspect of pest control became a highly lucrative venture.

INTEGRATED PEST MANAGEMENT

In 1985, an integrated pest management strategy was developed to curtail excessive dependence on chemical control of the leaf miner on potatoes (Rajabalee, 1990). It involved the improvement of biological control, studies on varietal resistance, trials with appropriate chemicals and efficient application techniques. The importance of proper cultural practices through appropriate planting time, weed free plantations and good seed material was stressed. The discovery of *Thrips palmi* in 1985 (Rajabalee and Ganeshan, 1988) and of the South American leaf miner *L. huidobrensis* in 1992 (Banymadhub and Rajabalee, 1992) and their large scale effect on potatoes and beans, justified even further the implementation of IPM. However, one main obstacle was the reluctance of the planting community to accept medium or long term solutions to pest problems. An aggressive attempt was made towards convincing the majority of planters of the overall advantages of IPM. This was carried out through sound extension work and on-farm demonstration plots.

Varietal Resistance

Potato varieties under cultivation are regularly monitored for their reaction to leaf miner damage. Among cultivated varieties, "Delaware" appears to tolerate leaf miner infestations more than "Spunta", "Mondial" and "Up-to-date" (Table 2).

The presence of glandular trichomes acts as a deterrent to egg laying. This characteristic is being used by the International Potato Centre (CIP) in Peru in its attempt to develop cultivars resistant to leaf miners. Various clones imported from this centre are being monitored for resistance to insect pests.

It has been noted that in beans, the primary cotyledonous leaves are very susceptible to leaf miner damage, while the secondary trifoliates, because of their high pilosity, are usually less so.

Table 2. Varietal resistance to *Liriomyza* spp.

Variety	No. of fields	Area (ha)	Age (weeks)	% Area with damage		
				Slight	Moderate	Severe
Delaware	28	48.74	8 - 11	78.0	22.0	0
Mondial	34	60.93	8 - 11	45.8	31.4	22.8
Spunta	17	41.75	8 - 11	37.3	44.8	17.9
Up-to-date	17	32.14	8 - 10	31.4	27.9	40.7

Biological Control

Known parasites of *L. trifolii* in Mauritius are *Hemiptarsenus semialbiclava*, *Chrysonotomyia* sp. *Meruana* sp. and an unidentified Cynipoid. To supplement their action, additional parasites were introduced, multiplied and released (Table 3). *D. sibirica* was recovered, and appears to have established itself while a *Chrysocharis* species was collected in very large numbers from *L. huidobrensis* on which it is the main parasite. The other species have not been recovered yet. Unfortunately, the multitude of adult *Liriomyza* flies and the scary appearance of leaf miner damage predominates the positive but invisible action of biological control, hence the tendency to resort to the use of pesticides.

Table 3. Releases of introduced leaf miner parasite in Mauritius

Parasite species	Source	Breeding period	Number released
Dacnusa sibirica Telenga (Braconidae)	IRAT-Reunio	Dec 1986 - Dec 1987	2433
Chrysocharis caribea Boucek (Eulophidae)	IRAT-Reunio	Dec 1987 - Aug 1988	383
Halticoptera arduine Dalman (Pteromalidae)	IRAT-Reunio	Sep 1988 - Aug 1989	448
Diglyphus websteri Crawford (Eulophidae)	CIP - Peru	Sep 1988 - Jul 1990	41
Diglyphus begini Ashmead (Eulophidae)	CIP - Peru	Sep 1988 - Dec 1988	41

(Source: Annual Report MSIRI 1989)

Chemical Control

It is known that chemical control will remain one of the main components of pest control in many crops, especially in third world countries. However, proper studies and sound extension work can still make pesticide use an acceptable component of IPM. Cyromazine is an insect growth regulator (IGR) and abamectine is a natural insecticide, both of which have been found to be very effective against leaf miners, while being harmless to natural enemies. Because of their high cost, acceptance by the planting community was slow. Through demonstration plots, it has been shown that less frequent sprays are required with the new products (Table 4). It is worth noting that interrow cultivation takes place over a short period of time, when the cane is still young and over a very limited area only.

Table 4. Comparative effects of IPM v/s conventional insecticide treatments against *L. trifolii*

	Benares		Bel Etang	
	IPM treatment	Conventional treatment	IPM treatment	Conventional treatment
No. of insecticidal treatments	1 Cyromazine 1 Pyrethroid	4 Methamidophos 3 Decis	1 Methamidophos 2 Pyrethroid	5 Pyrethroid (approx)
Average % leaf damage				
8 weeks	51.6	85.6	10.6	11.1
11 weeks	99.9	85.4	85.3	83.8
No. of leaf miner flies/g leaf	0.2	4.8	0.3	4.4
No. of parasites/g leaf	2.4	2.1	1.1	0.7
Ratio *L. trifolii* parasites	1:1.2	1:0.4	1:3.7	1:0.2

(Ref. Rajabalee 1990)

Defective spray applications may on a large measure be responsible for unsatisfactory results obtained with pesticides. Factors involved are:

1. Inadequate coverage
2. Excessive application rates
3. Incompatibility of mixed products
4. Drift

These factors may also result in agro-chemical pollution. However, a recent study has shown that at the rates now being applied, pesticides currently in use in Mauritius are not likely to cause pollution or present any risk to parasites of sugar cane pests. Growers should be made aware of the importance of proper nozzles and optimum application rates.

IMPLEMENTATION PROBLEMS

Sustained efforts on the part of scientists to adapt IPM to farmer level, should involve more farmer participation through sound extension work. This should take into consideration the socio-economic situation of the grower.

In Mauritius, acute labour shortage and high production costs are causes of concern in the agricultural sector. Increasing mechanization at all levels is being carried out. These changes in agricultural practices should not be at the expense of, but should be complementary to efficiency, this is more so where mist blowers or tractor mounted spraying equipment are concerned. Inefficacy of chemicals is often due to improper spraying techniques, as a result of which growers tend to use more and more of the product. This aspect of IPM is at present being studied.

CONCLUSION

The success of IPM depends on a realistic approach to its implementation. The role of the farmer and his constraints are often underestimated. He should not be presented with a stereotyped recommendation but with a list of methods complementary to one another, from which he can choose those more adapted to his needs. However, farmer education is essential for right decisions to be taken. With limitations imposed on chemical control, biological control is called upon to grow faster and be more productive. New technologies including use of entomopathogens, pheromones, and plans to make use of transgenic plants are seriously being considered in Mauritius.

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DISCUSSION

Youngquist : What methodology did you use to try and get farmers to adopt IPM ?

Rajabalee : Various methods including open days, direct contact with small farmers, restricting products through pesticide board.

Ampofo : Where did *Lironmyza* come from ?

Rajabalee : From Florida via Kenya and France via Rwanda.

Nyirenda : How do you monitor the effects of the parasites of the sugar cane pests, I presume this must be rather complex?

Rajabalee : We monitor the pests every 2-3 years and check the parasites.

THE STUDY OF THE BIOLOGY, POPULATION DYNAMICS, SPECIES COMPOSITION AND CONTROL METHODS IN ORDER TO DEVELOP AN INTEGRATED PEST MANAGEMENT (IPM) STRATEGY FOR THE MANAGEMENT OF FOLIAGE BEAN BEETLE, *Ootheca spp* (Coleoptera: Chrysomelidae)

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STATEMENT OF THE PROBLEM

In Tanzania, bean seed yield losses of 18% - 31% have been attributed to *O. bennigsenii* (Karel and Rweyemamu, 1984). However, in cases of severe infestation at early stages of plant growth total defoliation and 100% crop losses are realized. For example first sown crop at Lambo, Moshi and Lushoto, Tanga was completely destroyed by *Ootheca* (Slumpa, 1990 unpublished). The problem also exists in Ileje and Mbozi districts and parts of Rukwa region. In Morogoro region the insect problem has been reported by Karel and Rweyemamu, 1984.

BACKGROUND

Two species of the bean foliage beetles, *Ootheca bennigsenii* (Weise) and *O. mutabilis* (Sahlberg) are most damaging species of Chrysomelids found in Africa. They are reported from Kenya, Tanzania, Uganda, Burundi, Zambia, Malawi and Nigeria (Cardona and Karel 1990, Ochieng 1977), but their actual distribution is not well established. However, the importance of these two species in bean production was not reported by most countries, except Tanzania and Zambia during the entomology working group meeting held in Nairobi, Kenya, 1989. But recent observation by Dr. Ampofo (Personal communication) confirmed that the insect is an important pest of beans in some of the countries.

To further describe its importance, *Ootheca* was ranked number 5 among priority constraints (Table 1) in bean production in Tanzania. In the region, *Ootheca* ranked number 8 among insect pests hindering bean production. In setting these priorities, several factors (Figure 1) were considered as contributing to the importance of the pest in bean growing areas.

The adults are ca, 6mm long, with orange coloured head and shiny black/Orange elytra. To distinguish the two species, colour distinction has been used; *O. mutabilis* is shiny, light brown or light black (Ochieng, 1977; Singh *et al.*, 1990). Whereas *O. bennigsenii* has a light brown colour (Cardona and Karel, 1990). This method seems confusing and therefore important to use other methods e.g. description of male genitalia (Hills, 1906). However, the two colour monphs are often seen intermating: a more reliable character is the male genitalia (Hills, 1906) which is distinctive.

Ootheca females deposit their eggs in the soil near plant roots in clusters of 40 - 60. One female can lay up to 200 - 400 eggs. The depth of egg deposition ranges between 1.5 to 2.5 cm below the ground (Ochieng, 1977). The eggs hatch into larvae in about 11-14 days at room temperature of 25 - 32°C.

Since the eggs are laid in the vicinity of the roots of the host plant (Ochieng, 1977), the larvae tend to feed on the roots. Three larval instars are recognized, all together lasting for 40 - 45 days, then it changes into pupa which takes 14 - 20 days. These insects have a tendency to diapause in order to survive in the dry period.

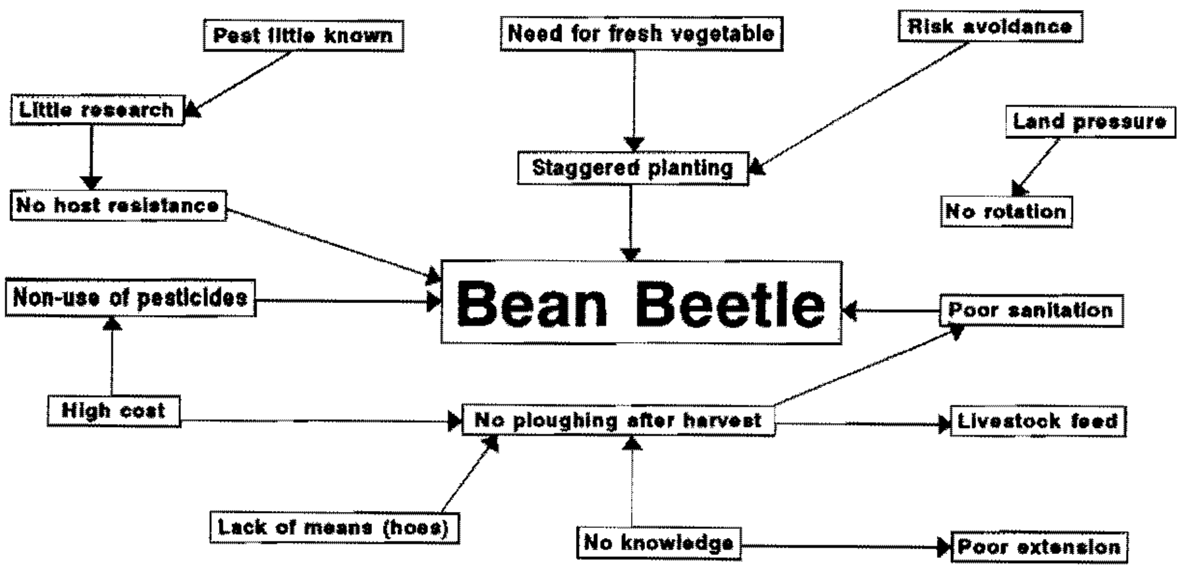
Table 1. Setting regional priorities among constraints.

Constraints	1st rank	Ranks by Participants											Total	Final rank
		1	2	3	4	5	6	7	8	9	10	11		
1. BSM	1	1	2	15	3	1	2	3	3	8	4	2	44	1
2. ALS	3	3	4	6	10	2	1	1	2	9	12	5	55	2
3. BRUCHID	2	4	7	2	4	3	4	4	1	10	6	7	52	3
4. RUST	11	8	10	5	13	5	8	11	6	15	14	18	113	8
5. OOTHECA	12	2	6	10	17	10	9	5	7	20	16	13	115	8
6. ANTHRANCOSE	10	7	12	14	2	8	15	12	8	11	11	6	107	10
7. WEED	7	5	14	4	9	7	10	13	11	5	9	3	90	12
8. LOW Y.P	6	6	1	13	1	11	7	10	13	7	5	8	82	12
9. CBB	18	18	18	11	18	19	18	9	12	18	18	14	173	17
10. POD B.	17	17	17	12	20	12	16	14	16	17	19	12	172	19
11. LOW N	5	9	5	7	6	4	3	7	15	6	3	10	75	3
12. SEED AV.	9	16	3	8	11	13	19	2	9	2	10	9	102	5
13. SEED QUAL.	4	15	8	1	6	13	6	4	3	2	1	1	71	5
14. LOW P.	8	10	9	19	5	9	5	15	14	1	1	4	92	5
15. OTHER CHEM	19	19	12	18	14	17	17	17	17	16	20	20	187	10
16. DROUGHT	13	11	11	3	19	14	11	8	5	12	13	15	122	12
17. EROSION	14	12	16	9	15	16	14	18	18	13	7	11	149	17
18. LOW PH	15	14	15	17	7	15	6	16	19	14	15	17	155	19
19. OTHER SOIL INFE.	20	20	20	20	8	20	12	19	20	19	17	19	194	19
20. LAND PREP.	16	13	19	16	16	18	20	20	20	4	8	16	160	19

Source: The SADCC/CIAT's Planning Workshop held at Makokola, Mangochi, Malawi from 6-8th March, 1991.

The larvae go through three instars which last 40 - 45 days all together. The pupal stage lasts 14-20 days. The insect goes through a state of diapause in an earthen cell during the dry season. The emergence of the adult is synchronized with the onset of the rains and crop emergence. That means there is a relationship between softening of the earthen cell and emergence of the adults. In this respect therefore irrigation could also facilitate adult emergence. However, infestation is more severe during the onset of the rains and the early sown crop is likely to be more severely attached.

Figure 1. Factors contributing for the importance of Bean Foliage Beetle (*Ootheca* spp).



Source: The SADCC/CIAT's Planning Workshop held at Makokola, Mangochi, Malawi from 6-8th March, 1991.

The damage by these chrysomelids is done by both larvae and adults. The larvae feed on bean roots and nodules thus interfering with the nutrient transport system and nitrogen fixing ability of the plants. On older plants, signs of damage by larvae can be recognized by weak yellow plants with fewer and shrivelled pods, as a result of premature senescence.

The adults feed on leaves, making interveinal holes and plants become skeletonized, thus impairing photosynthetic activity. All crop stages are attacked though seedlings are more vulnerable and severely damaged In addition, adults of chrysomelids have been implicated as vectors of some viral diseases in cowpea such as cowpea mosaic and cowpea mottle (Gamez, 1980; Singh and van Emden, 1979). In beans, virus transmitted diseases by *Ootheca spp* need to be investigated.

POSSIBLE CONTROL MEASURES

CULTURAL CONTROL

(i) Delayed planting

prolonged delays may expose the crop to severe infestation by bean stem maggot. But through time of sowing studies it is possible to determine a period whereby both heavy attacked by insects can be escaped.

(ii) **Intercropping beans with maize**

The population of chrysomelids is said to be reduced by growing bean in an intercropped situation. (Risch, 1980).

(iii) **Development of resistant materials**

Resistance has been implicated as a promising approach for the control of *Ootheca*. The mechanism of resistance is described as non-preference and tolerance (Karel, 1985b; Karel and Rweyemamu, 1984).

(iv) **Post harvest plowing**

Expose eggs, Larvae and diapausing adults to the unfavourable environment to impair their development. This could be at an extra cost especially for small scale farmers.

Natural enemies

Two predators (Ants, *Monomorium* sp. (Hymenoptera: Formicidae and Reduviid bug, *Phinocoris bicolar*) of *O. mutabilis* have been identified. The former being predator of eggs and the latter predator of adults (Ochieng, 1977). However, the effectiveness of these natural enemies is not well studied.

CHEMICAL CONTROL

The use of insecticides for the small scale farmers tend to be very expensive in terms of cash and improper handling. In addition, the use of chemical weapon in agriculture threatens the health of the environment. However, it is the only control measure we have at hand for the control of *Ootheca*.

PROJECT JUSTIFICATION

The above background information indicate that there is limited work done on various aspects, and some of the findings are inconclusive for any inferences to be drawn for recommendations.

(a) **Purpose**

To study various aspects of the insect such as biology, ecology, species composition and develop its control strategies.

(b) **Reasons for undertaking the project**

To develop IPM package to be recommended for use by small scale farmers for the control of *Ootheca*, finaly improve bean production.

(c) **Specific problem definition**

Defoliation caused by bean foliage beetles results in higher yield losses in bean production.

(d) **Objectives**

(i) To study the biology of the 2 species of bean foliage beetle.
(ii) To determine species composition of these species of bean foliage beetle and their distribution in the bean growing areas of Tanzania.
(iii) To study population dynamics and establish damage levels in relation to yield losses due to the foliage bean beetle.
(iv) To identify natural enemies and investigate their effectiveness for the control of bean foliage beetle.
(v) To identify various alternate hosts for foliage bean beetle
(vi) To develop and evaluate different management practices in various combinations (IPM context) for the control of bean foliage beetle both on farmers fields and on station.

TIME FRAME

The proposed research project is expected to be accomplished in 4 years.

WORK PLAN

Study will be accomplished in three sub-projects:

Sub-project 1: Study on the biology of bean foliage beetle species prevailing in Tanzania.
Sub-project 2: Study on the emergence pattern, species distribution, composition and population dynamics.
Sub-project 3: Study on the control strategies for the bean foliage beetle.

Study on the biology of bean foliage beetle species prevailing in the region

Collect from the fields in Arusha and Kilimanjaro regions, pairs of freshly emerged adults and monitor their pre-oviposition behaviour in terms of number of times they mate, mating time and pre-oviposition time i.e. time between mating and oviposition*

Arrange at least 10 petri dishes. In each dish put small amount of moist soil. In the same petri dishes place fresh young leaves of beans. Then release in each petri dish 3 pairs of mating adults, observe the petri dishes for any oviposition after one day. On the next day, arrange another set of 10 petri dishes with new soil and fresh leaves as in (ii) and transfer the adults from number (i) into these new set of petri dishes. Extract and count eggs oviposited in the first set of petri dishes. Also note the number of clusters and number of eggs per cluster. Transfer the eggs to other clean petri dishes with fairly moist filter paper.

Make sure that the dishes are kept slightly moist every morning.
Repeat procedure number (iv) until the females cease oviposition.
* Oviposition will be monitored daily in the screen house and laboratory at a known temperature and relative humidity to determine:

(a) the pre-oviposition period and
(b) the peak oviposition period.

Sow in a transparent plastic container two seeds of Lyamungu 85, sow the seeds at the edge/sides of the container so that the growth of the roots and development of the larvae can be observed. The plastic containers will be wrapped with aluminum foil to block light since roots are negatively phototropic. When the plants are at primary/first trifoliolate leaf introduce the first instar larvae in the soil about 1.5 - 2.5 cm below the soil surface. Place it on the sides near the seedling. This will enable easy monitoring of larva development.

Data collection and recording

(A) Description of eggs

- (i) Observe number of clusters and count number eggs per cluster.
- (ii) Count number of eggs per female.
- (iii) Count number of eggs which hatched into larvae and the number of days it takes to hatch.
- (iv) Note any observations with unhatched eggs.
- (v) Describe shape, colour and size of an egg (use a micrometer eyepiece).

(B) Description of larvae

- (i) Measure body length (mm) and width (mm)
- (ii) Take measurement of the head capsule width (mm) and length (mm) in order to differentiate/discriminate between the different instars.

This can be done in two ways.

- (i) Measuring the head capsule after every moult.
- (ii) Measuring the head capsule width of all the collected larvae, then put them in a class categories according to their measurements (eg 0-0 1 mm, 0.11 - 0.2 mm, 0.21 - 0.3 mm)and plot the frequency distribution of head capsule width against number of larvae falling in different categories. Eventually the peaks and depressions of the frequency distribution will determine the number of instars.
- (iii) Note any larval mortality, most affected stage and the cause of the mortality.
- (iv) Record number of days it takes a larva to change into a pupa.

(C) Description of the pupa.

- (i) Pupa period (days).
- (ii) Shape, size and colour.

(D) Diapause stage

Subject some containers to differential dry periods 10, 20, 40, 80, 160 and 320 days and record adult emergence.

(E) Observe life span of the adult beetle.

Study on the emergence pattern, species distribution, composition and population dynamics

The locations to conduct this experiment will cover a range of environmental climatic conditions in terms of altitudes, temperatures, rainfall and soil types. The adults will be collected from the proposed locations from the onset of the long rains through the short rains. The study on population dynamics and damage levels in relation to yield losses will be accomplished through time of sowing at weekly interval starting from the on set of rains until the end of the season.

For a start, regions in Northern Zone are proposed:

Arusha:	-	Selian (1387 masl) Babati (1500 masl)
Kilimanjaro:	-	Lambo (1020 masl) Lyamungu (1298 masl)
	-	Miwaleni (560 masl)
Mbeya:	-	Ileje
	-	Mbozi
Morogoro:	-	Morning side/SUA
	-	Ilonga
Tanga:	-	Soni (850 masl)
	-	Mabughai (1560 masl)

Data collection and recording

Count adults in demarcated area of 1 m^2 and then collect 20 adults for identification into different species in the laboratory. Three samples will be taken per field at weakly interval. The sampling will be done in the morning because in the afternoon the adults become so active to count.

Preserve them in glass vial containing alcohol (Konyagi) indicate dates, location, altitude, rainfall, temperature, humidity and previous history of the field.

Make observation on host range.

Dig around the bean plants showing sign of damage by *Ootheca* and collect larvae (if any).

To study and evaluate various control strategies for bean foliage beetle.

Experiment 1: Screening bean cultivars for bean foliage beetle resistance.

CIAT materials: A62, A67, A87, BAT 1252 and Uyole materials: Kabanima, Mexican 142, T8, UAC 116 and YB-2 that have shown some tolerance, will be included as checks plus other released varieties. Other materials will be provided from the germplasm in the national programme collection and land races from different location will be included.

Experiment 2: Influence of time of sowing on bean foliage beetle *(Ootheca spp)* infestation and damage.

In this section, trials will be conducted in different locations of different weather conditions in Northern zone this will involve several times of sowing commencing from the onset of rains.

Experiment 3: Assessment of infestation and damage by bean foliage beetle in different cropping systems. Bean with Maize, Coffee and Banana cropping systems depending on common practice in the area eg relay cropping with maize in Mbozi and Mbeya rural districts.

Experiment 4: Insecticides screening for the control of foliage bean beetle Evaluation of various seed dressings and foliar sprays insecticides for their efficacy to control bean foliage beetle. Preferably insecticides with low mammalian toxicity and less residual effect to avoid hazards to the public and the environment.

Data collection and recording

(i) Count the number of *Ootheca* in a specified area.
(ii) Score the damage on a scale of 1-9; where as 1 = no damage and 9 = severe defoliation.

Experiment 5: Search for possible natural enemies for the control of bean foliage beetle.

It is important to look and assess the cause of mortality at different stages in the life cycle of the insect.

These include
- Parasites
- Predators
- Fungi pathogens

Experiment 6: Assess other cultural practice like sowing dates, post harvest ploughing and put together an IPM package based on these findings and information obtained in experiments 1, 2, 3 and 4.

NB: Farmers and extension workers experiences will be included in the initial development of the integrated pest management (IPM) package. In the process, various combinations of components expected in developing IPM will be evaluated on station. Later, the few most effective combinations will be tested under farmer's conditions.

Collaborating institutions

Uyole Agriculture Centre

- Collection and identification of species prevailing in different altitudes of southern highlands.
- Testing and assembling of various components of IPM on farmers fields.

Sokoine University of Agriculture

- Collection and identification of species prevailing in different altitudes of Morogoro.
- Testing and assembling various components of IPM on farmers fields.

CIAT BEAN PROGRAMME

- Investigate the role of *Ootheca* spp in the transmission of virus diseases in beans.

Other international organization to be consulted for identification of specimen and literature review are:- (1) IITA. (2) ICIPE. (3) Commonwealth mycological institute (CMI). (4) Commonwealth institute of Entomology (CIE).

Expected Statistical Analysis

Through MSTAT-C computer program: 1. Anova 2. Mean separation test.

ASSUMPTION

(i) We expect farmers and extension workers to contribute their experiences in the initial development of the IPM package.
(ii) Availability of funds for the implementation of the project.
(iii) Farmers accept to adopt recommended IPM package.

EXPECTED IMPACT

Farmers will be able to use technologies developed specifically the IPM package for controlling *Ootheca*. Hence increased yield per unit land area due to increased number of plants at harvest and reduced destruction of photosynthetic active leaf area by *Ootheca*. These methods are expected to be less costly and environmentally friendly. These low-input technologies and ecologically sound methods have sustainability implications.

INPUTS

(1) **Human resources**

4 entomology	Mr. Slumpa (M.Sc) Selian National bean Program. Dr. J.K.O. Ampofo (Ph.D) CIAT bean program. Mr. D. Kabungo (B.Sc) Uyole Agriculture Centre. Mr. D. Mushobozi (M.Sc) Sokoine University of Agriculture.
1 Pathology	Mr. D. Ngulu (M.Sc) Selian National Bean Program.
2 Breeders	Dr. C.S. Mushi (Ph.D) Selian National Bean Program. Mr. S.O. Kweka (B.Sc) Selian National Bean Program.
1 Agronomic	Mr. P. Ndakidemi (M.Sc) Selian National Bean Program.

(2) **Facilities/Equipments**

- Screen house and laboratory at Selian agriculture Research Institute.
- Laboratory at Sokoine University of Agriculture.

BUDGET JUSTIFICATION

The funds from DRT are limited to facilitate implementation and purchase of materials equipments for the proposed project.

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DISCUSSION

Gethi : There are two species of *Ootheca* on cowpeas, is this different on common beans?

Slumpa : Studies done in Nigeria need to be repeated in the region, work needs to be done on distinguishing species. Colour is not a good indication.

Ampofo	:	We don't know enough about biology, is *O. mutabilis* or *O. bennigsenii* on beans. How are you going to approach strategies for control ?
Slumpa	:	I will include cultural practices, intercropping, screening for resistant germplasm.
Ampofo	:	No resistance was found with *Diabrotica* spp. in south America and I do not have much hope here but the role of natural enemies could be explored.
Nderitu	:	One of your priorities is species identification. Do you have a detailed key for this purpose?
Slumpa	:	Ther is no clear key in the literature.
Agona	:	Will lab studies of biology be successful, if these insects are lab shy ?
Slumpa	:	We had no problem with oviposition in petri dishes. The problem is to rear them to pupation.

ECOLOGICAL FACTORS AFFECTING THE POPULATION DYNAMICS OF THE BLACK BEAN APHID *APHIS FABAE SCOPOLI* AND THEIR ROLE IN THE EPIDEMIOLOGY OF BEAN COMMON MOSAIC VIRUS (BCMV)

INVESTIGATOR - Dr. Macharia Gethi - Entomologist
COLLABORATOR - Mr. L.M.Muriithi - Pathologist
SITE - RRC Embu; Farmers Fields
DURATION - 3 years
Start - Long Rains 1993

INTRODUCTION

In Kenya bean, *Phaseolus vulgaris* (L.) is a very important pulse crop which ranks second to maize in importance. Bean growers consisting of small scale farmers realize yields of about 300 - 700 kg/ha. when the crop has a capacity of producing up to 3000 kg/ha (Anon 1978). These low yields of field beans are attributed to severe damage by insect pests and diseases (Karel *et al.*, 1980). Among the most important pests are the Agromyzid beanflies of the genus *ophiomyia*, the black bean aphid, *Aphis fabae* Scopoli and the African bollworm *Heliothis armigera* Hubner (Wallace, 1941; Greathead, 1968; Singh and Van Emden, 1979; Njuguna *et al.*, 1980).

The black bean aphid (*A. fabae*) though sporadic is a serious pest of beans mainly during the second season (short rainy season) in Kenya's ecozone 2(UM2) (Omunyin *et al.*, 1984; Khamala, 1978). Its damage is threefold namely the withdrawal of plant sap, mechanical injury to the plant and above all the transmission of common bean mosaic virus which is a serious disease of the field bean in East Africa (Wallace, 1939, 1941; Kaiser, 1976; Khaemba and Latigo, 1981). Rataul (1969) found that four other aphid species namely *Aphis gossypii*, *Myzus persicae* and two species of the genus *Microsiphum* were capable of transmitting BCMV in a screen house. The general symptoms of the disease are reduced plant growth, dwarfing, malformation and severe physiological disorders leading to plant death (Kulkami 1972; Barlow 1973):

Control of viral diseases is believed to continue mainly,through the incorporation of immunity and resistance. However, in Kenya, field experiments have shown that from a wide range of germplasm tested for resistance to BCMV only a few seem to have some resistance to BCMV with the majority being very susceptible (Omunyin *et. al.*, 1984).

The control of the vector has also proved difficult due to its reproductive behaviour. Ingram (1969) indicated that insecticides were not very effective. He showed that after insecticide application the mortality is high but re-infestation particularly of the winged (alatae) stages is almost immediate resulting to no reduction in the infestation. A large number of coccinellids, *Epilachna* sp. and *Cheilomenes* sp. have been found to be predators of aphids in the field. Yassin and Dufalla (1980) demonstrated the spread of BCMV to be very random, an indication of the random movement of the aphids. The preceding information reveals that it is difficult to control the spread of BCMV with the control of the aphids. It is expected then, that if the control of BCMV is to be achieved through the incorporation of resistance and immunity, better knowledge of the vector and its host may facilitate the disease management. It is also imperative that investigations of the biometeorological variables should be conducted in order to be able to predict BCMV incidence and its severity under field conditions.

There is scanty information on how environmental factors do affect or influence the symptoms of BCMV expressed, it is therefore in this view that studies will be initiated to investigate how ecological factors affect the population dynamics, of the vector and their subsequent effect on the epidemiology of BCMV. When this kind of information is obtained it will go a long way in assisting researchers and more so the farmers in predicting occurrence of BCMV and the appropriate time to control the aphid. It is also important that this kind of project be collaborative in that the researchers involved will be able to exchange information and complement each other's activities.

THE MAIN OBJECTIVES OF THIS STUDY ARE TO:

(a) Study the ecological factors that do affect the population dynamics of *A. fabae*.
(b) Identify other aphid species that are capable of spreading BCMV in the field.
(c) Study the epidemiology of BCMV in relation to environmental conditions.
(d) Study the level of BCMV transmission by different aphid species (infectivity).

These objectives will be achieved by testing the hypothesis that:-

(a) Ecological factors determine the population build up of the aphids.
(b) Species of aphids other than *A. fabae* do spread BCMV.
(c) Spread of BCMV is dependent on the species diversity of the aphid and microenvironment factors.

MATERIALS AND METHODS

These studies will be conducted at RRC EMBU main station and in the farmers fields. A susceptible and a resistant cultivars to be obtained from the grain legume project at Thika will be used. The purpose of using these two cultivar is to help in determining whether they are susceptible or resistant to BCMV or to the aphid.

Population dynamics studies

To determine the population dynamics of the aphid, two blocks measuring 20 x 20 m one containing the resistant bean cultivar and the other a susceptible one will be planted in the main station at a spacing of 75 x 10 cm. Each block will then be sub-divided into 36 equal sub-plots immediately after plant emergence. Within each block, 6 traps will be set in some of the subplots selected at random. Traps (3) will be sticky traps made of hurricane lamp glasses while the other 3 traps will be plastic basin containing water and set in the middle of the subplots. The hurricane lamp glasses will be covered with a yellow plastic sheeting smeared with grease while some detergent will be used in the water traps to reduce surface tension. This method of trapping aphids to study their activity over the growing season has been used by Ingram (1969) and he obtained consistent results. The objective of using both traps is to compare the efficiency of these traps. The traps will be set immediately after plant emergence. Records of aphid catches will be taken weekly.

Population dynamics studies will also be conducted in farmers' fields in four different locations representing the four agroecological zones where beans are grown (UM1, UM2, UM3 and UM4). Six traps will be scattered throughout the farmers bean fields. Records of aphid catches throughout the season will be taken at weekly interval.

A. fabae sampling from plants

A major problem with studying population dynamics of aphids in general is the estimation of large population of aphids on a plant. Many workers have used different methods of estimation (Amman, 1967; Kumar, 1971; Banks, 1954). For the purpose of studying population dynamics and infestation of aphids during these studies, a method used by Srikanth and Lakkudi (1988) will be applied. From six subplots selected at random from each block, 10 plants also selected at random will be used to estimate the population density of the aphids on different parts of the plant. This will be done as follows:

(i) Density on leaves, stems and pods:

Three classes of infestation will be used.

(a) Heavy: 75 - 100% of stems and young pods completely covered by dense colonies of the aphid and appear black.
(b) Medium (40 - 75%) large portions of stem and pods covered by aphid colonies distinct but not continuous and portion of stems and pods visible.
(c) Low: 0 - 40% of the plant with scattered aphids on the stems and pods, colonies absent and major portions of stems and plant visible.

(ii) Density on leaves:

(a) Heavy: Lower surface of leaflets completely covered by aphids the surface appearing black due to dense crowding of aphids.
(b) Medium: Large number of aphids present in one or two distinct colonies.
(c) Low: Few aphids to a single colony present.

The infected plants will then be collected in plastic containers and taken to the laboratory. The aphids will then be dislodged on a white paper and using a camel hair brush, their number will be counted. The mean population density will be expressed as the number of aphids per cm^2 an area estimated from the 10 samples in each class.

Aphid species composition

From the samples of the aphids collected from the sticky traps, water traps and individual plants from the field (station and farmers field), aphids will be put in glass vials containing 70% alcohol. These samples will then be taken to National Agricultural laboratories and some to the National Resources Institute in London to determine aphid species present.

Ecological factors

It is a well known fact that differences in temperature and relative humidity and amount of rainfall influence the determination of pest population densities. On the same lines it is proposed that these parameters will be recorded from both the station plots and the farmers' fields. Weekly means of temperature and relative humidity will be taken using a thermo-hydrograph while rain gauges will be set in each plot in all agroecological zones to determine the amount of rainfall received weekly. The data obtained will be used to determine the correlation between aphid infestation processes in relation to BCMV incidence and weather factors.

Epidemiology of BCMV

To determine the severity and incidence of BCMV in relation to aphid populations and ecological factors, a scale developed by CIAT will be used. This scale consists of three variables, namely, symptoms, incidence and yield. Symptom - Plants collected from the two blocks will be examined for presence or absence of the symptoms. The general evaluation scale to be used will be as follow:-

Rating	Symptoms	Incidence	Yield
1	Absent	0	Excellent
2	Doubtful	1-10	-
3	Weak	11-25	Good
4	Moderate	26-40	-
5	Intermediate	41-60	Intermediate
6	General	61-75	-
7	Intense	76-90	Poor
8	Severe	91-99	-
9	Death	100	Very poor

The data obtained will be used to estimate the relationship of BCMV incidence and aphid population build up together with variations in weather factors.

BCMV transmission (infectivity) by different aphid species

After the aphid species are identified in section 8.2., laboratory reared colonies will be released on infected plants, allowed to feed for about 6 days, then will be transfered into one week old healthy bean plants. This will be done in a screen house to test the infectivity of different aphid species in transmitting BCMV. A susceptible bean variety will be used. Seeds will be planted in plastic pots. The pots will be arranged in a factorial design with 4 replicates. The number of treatments will depend on the number of aphid species identified in section **8.2.** Development of BCMV will be monitored starting one week after the introduction of aphids previously recovered from diseased plants.

EXPECTED RESULTS

It is expected that at the end of the project, the data will be able to reflect the following:-

(1) Effect of temperature, relative humidities and rainfall on the population dynamics [winged aphid (dispersing alatae)]. This will help in determining when to apply control measures on the vector.
(2) Whether resistance is due to vector preference or BCMV tolerance.
(3) Stage of growth that is susceptible to BCMV.
(4) Aphid species present in various agroecological zones. This will form a base line for future biological control studies.
(5) Trap effectiveness in monitoring vector populations.
(6) Relationship between weather factors and symptoms of BCMV expressed in order to predict disease incidence.

The results will form a baseline for future work on integrated management strategies.

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DISCUSSION

Kabungo : Are you going to use resistant varieties ?

Gethi : Yes, 1 resistant, 1 susceptible

Kabungo : Have you identified the resistant variety ?

Gethi : Work is still going on at the moment.

Kabungo : Procedures already exist developed by the regional sub-project in Zambia. Have you consulted them ?

Gethi : Not yet but comments on the proposals are welcome.

Ampofo : We have to decidewhat we mean by resistance in this case. Are we talking about resistance to the aphid or to the disease.

Gethi : That is what I am to find out.

Ampofo : Transmission studies were not done by the previous sub-project perhaps attention could be focussed on that area.

Youngquist : Several genes confer resistance to BCMV and transfer of these genes is straightforward. Is there problems with aphids apart from BCMV?

Gethi : Yes, aphids can kill the beans in the second season.

Youngquist : It would be better to concentrate on the pest aspect.

Nderitu : Information flow in the network appears to be bad.

Ampofo : Data are usually presented in the workshops, is there need for a newsletter?

PARTICIPATIVE PLANNING PROCESS

The procedure used was based on a blend of project planning designs from "The Project Planning by Objectives (PPO or ZOPP)" and "The Planning Stage of On-Farm Research: Identifying Factors for Experimentation" by Tripp and Wooley (1989). The steps involved:

1. Problem identification (Identification of key pests that constrain bean crop productivity in the region).
2. Priority setting among the key pests of beans.
3. Identification of causes and events that lead to the pest constraints and their effects.
4. Identification of potential solutions and priority setting among them.
5. Implementation strategy, including project design and documentation.
6. Resource allocation for research and development of solutions to key pest problems.

Six pest species and species complexes out of a total of over twenty species listed by participants as constraining bean productivity in the individual countries were identified as key pests for research focus within the region (see Tables 1 and 2).

Table 1. Ranking of top eight pest groups by participants from the different countries

Country	Pod borers	Bean stem maggot (BSM)	Leaf Hoppers	Bruchids	Ootheca	Pod Bugs	Aphids	Thrips
			Ranks by Participants					
Kenya	3	3	3	1	1	2	3	3
Tanzania	2	1	3	1	1	1	3	3
Mozambique	2	1	3	1	1	2	3	3
Zimbabwe	3	1	3	1	1	2	3	3
Uganda	3	1	3	1	1	2	3	3
Malawi	2?	1	2?	1	1	2	1	1
Sudan	3?	1	3	3	3	3	1	1
Zambia	3	1	3	1	1	2	3	3
Great Lakes	1	3	2	2	2	2	2	3
Mauritius	3	1	3	3	2	2	3	3
Ethiopia	2	1	3	1	1	1	3	3
	27	15	29	16	15	21	26	29

1 = Very important 2 = Important 3 = Less important 4 = Absent or not important

Several other pests were considered as of localized importance e.g. leafminers in Mauritius, whiteflies in Somalia etc. In such cases the individual National Programmes were encouraged to tackles them directly and to request technical assistance from the regional programme, the regional entomologist or other entomologists as necessary.

Table 2. Analyses of key pests, their frequency of occurrence and severity of damage.

Problem	Frequency of occurrence		Severity of damage (1-3)	Priority (1-4)
	Fields (1-3)	Seasons (1-3)		
Pod Borers	3	1	3	2.3
Bean Stem Maggot (BSM)	1	1	2	1.3
Leaf Hoppers	3	3	3	3.0
Bruchids	1.5	1	2	1.6
Ootheca	2.1	2.5	2.5	2.3
Pod bugs	2	1.9	2.8	2.2
Aphids	1.8	1.7	2.1	2.9
Thrips	1.7	1.6	2.5	1.9

Having identified the key pests of regional importance, the causes and effects of their increased incidence, attack and severity of damage including the interactions among them were analyzed as described in Figure 1 to 6.

IDENTIFICATION OF CAUSES AND EVENTS THAT LEAD TO THE PEST CONSTRAINTS, THEIR INTERRELATIONSHIPS AND EFFECTS (FIGURE 1-6)

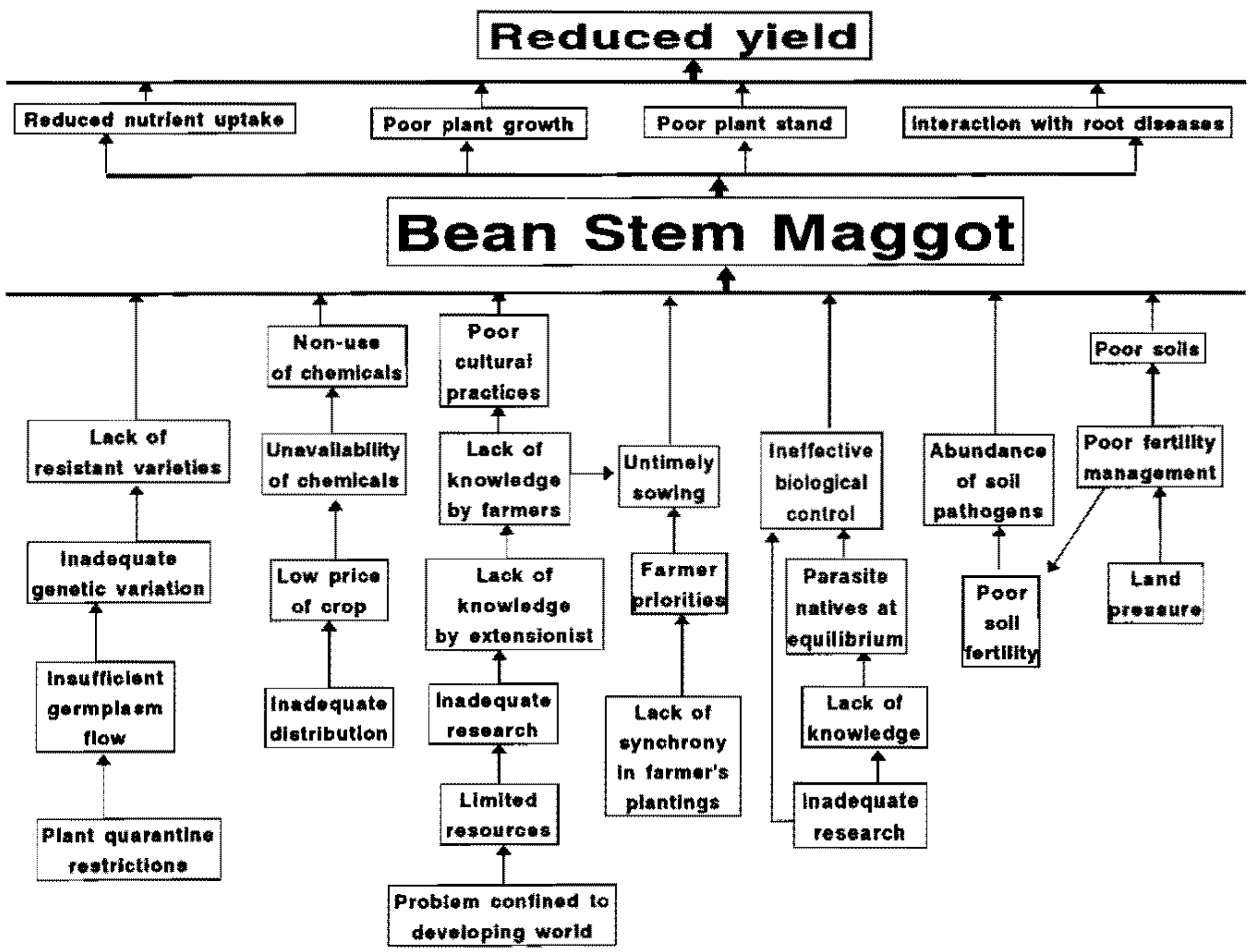
BSM

Figure 1 shows the causes and effects of high BSM damage and inter-relationships among them. The more direct causes of the BSM problem are:

1. Lack of farmer knowledge of the pest.
2. Lack of tolerant varieties.
3. Poor cultural practices.
4. Recommended chemicals unavailable to, or seldom used by farmers.
5. Inadequate control by natural enemies.
6. Infertile soils.
7. Strong interactions with soil borne diseases.

These causes lead to reduced nutrient uptake, increased incidence of root disease attack, poor plant growth, reduced plant stand and overall reduction in yield.

Figure 1. Causes and effect of high BSM damage and inter-relationships among them.



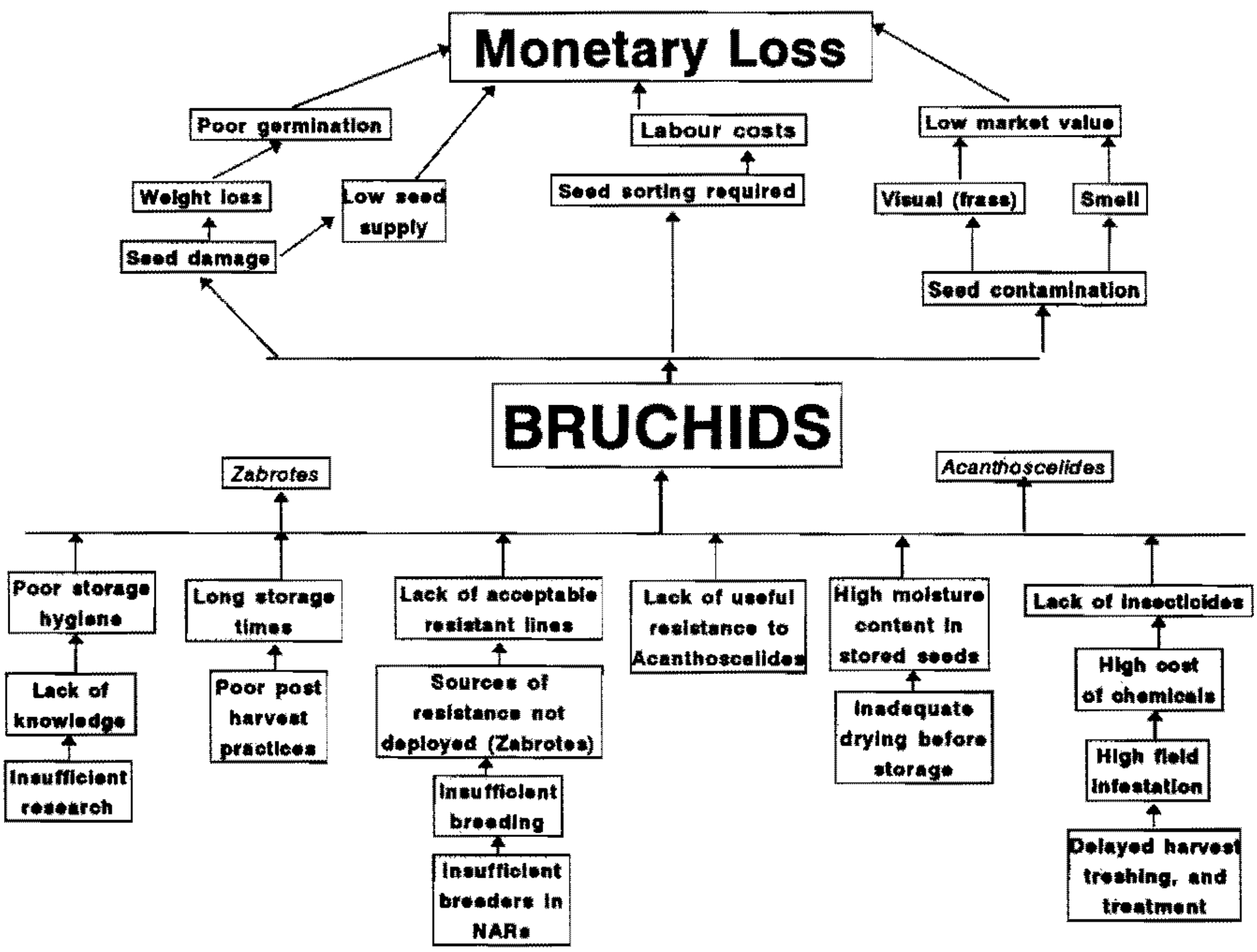
Bruchids

Figure 2 shows the causes and effect of high bruchid infestation and damage, and the inter-relationships among them. The primary causes of the bruchid problem are:

1. Poor storage hygiene (especially in the case of *Zabrotes*).
2. Lack of resistant varieties in the case of *Acanthoscelides*, and resistant varieties unavailable to farmers in the case of *Zabrotes*.
3. Lack of insecticides for storage.
4. Traditional storage methods sometimes ineffective.

These create quantitative losses such as poor plant emergence, seed contamination (holes, frass, fungal infection and bad odour) and quantitative losses such as reduced seed weight, leading to poor marketability of the produce.

Figure 2. Causes and effect of high bruchid infestation and damage, and inter-relationships among them.



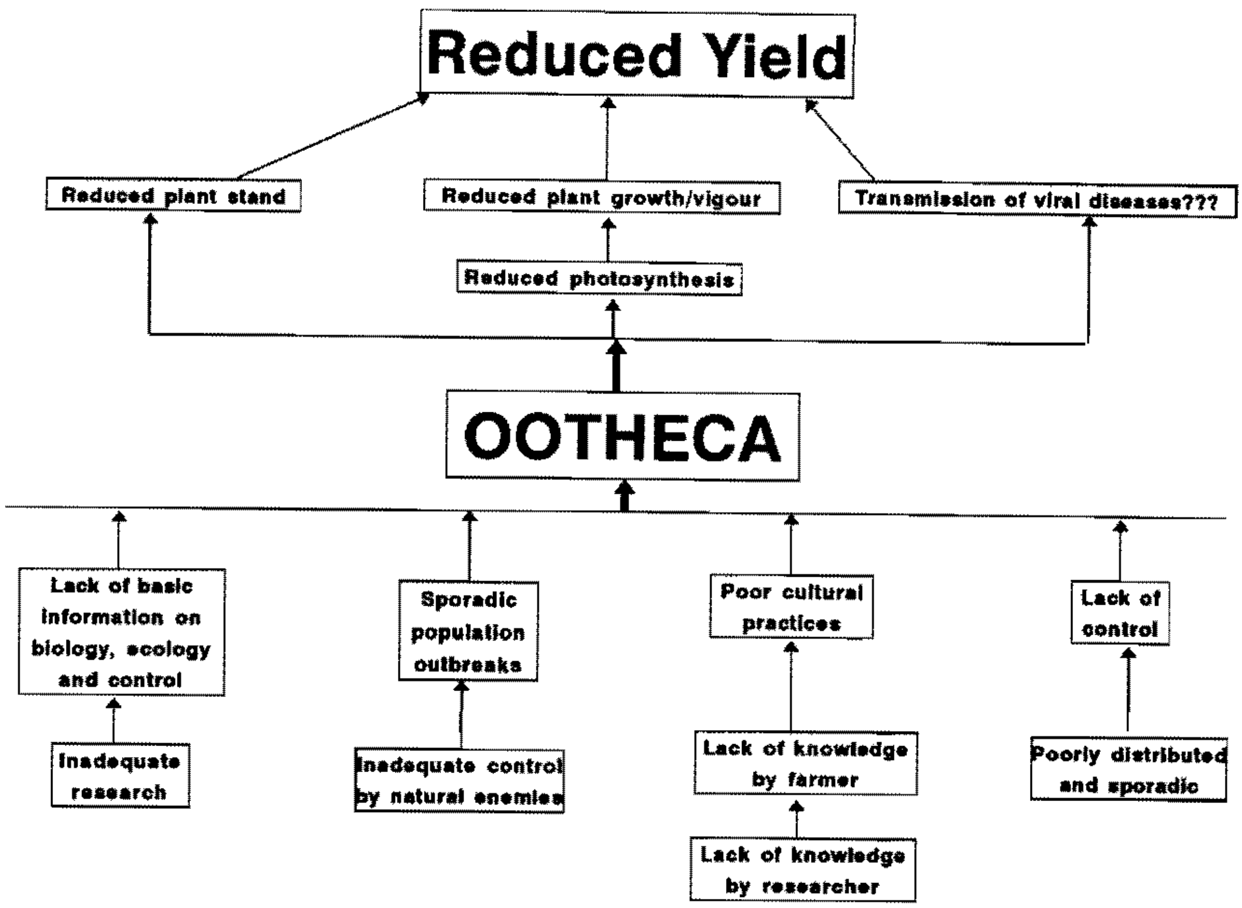
Ootheca

Figure 3 shows the causes and effect of high *Ootheca* infestation and damage and inter-relationships among them. The primary causes of the problem are:

1. Poor cultural practices e.g. untimely planting that allows the young crop to coincide with peak population levels.
2. Lack of basic information on pest biology, ecology and control.
3. Sporadic population outbreaks.

Ootheca infestations reduce leaf area and photosynthetic capacity of plants leading to poor plant vigour and growth and in some cases plant mortality and reductions in plant stand. *Ootheca* infestations are associated viral transmission in some crops but this is not confirmed in beans.

Figure 3. Causes and effect of high *Ootheca* infestation and damage and inter-relationships among them.



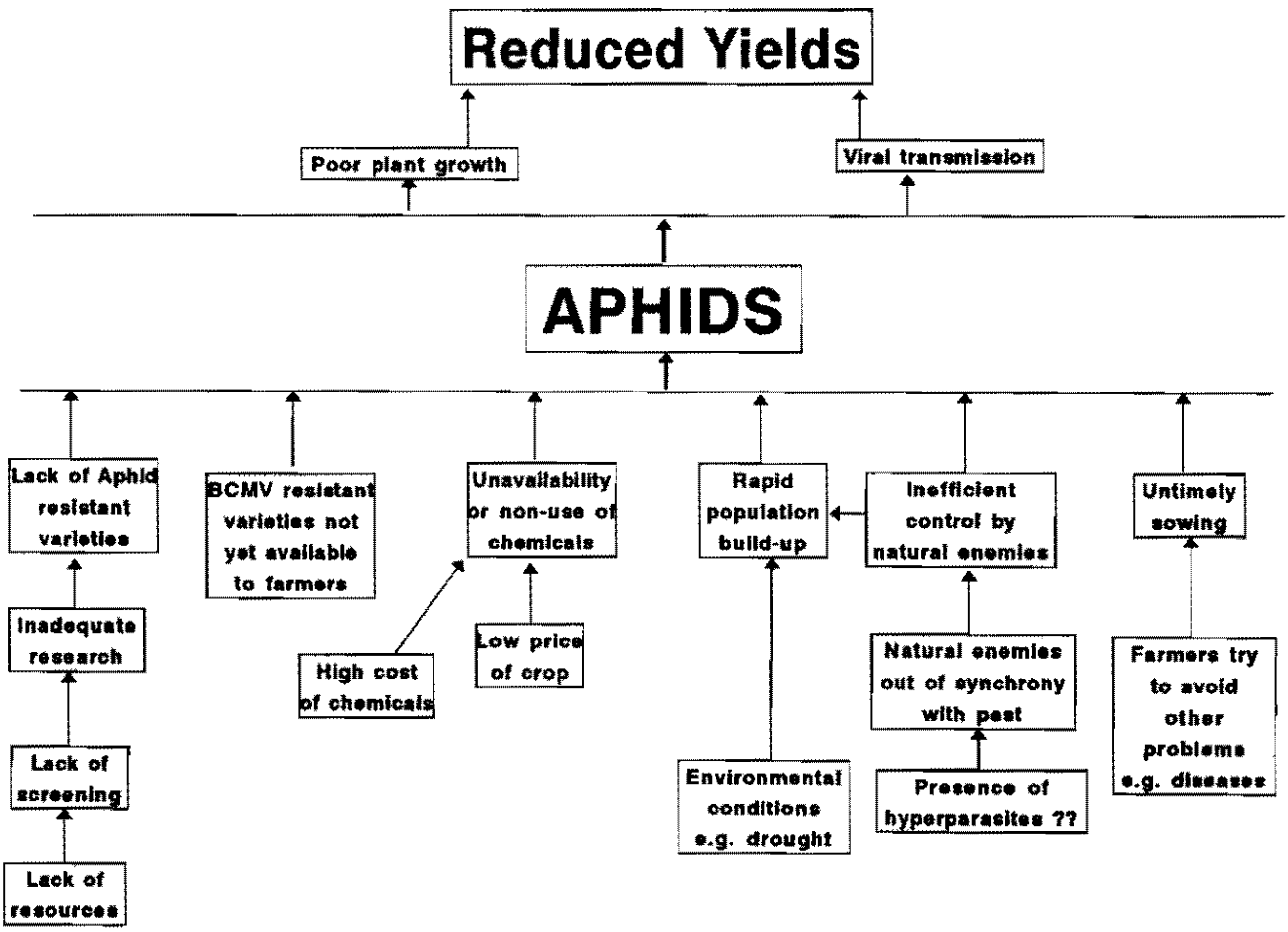
Aphids

Figure 4 shows the causes and effects of high aphid infestation and damage including their effect in the spread of viral disease and the inter-relationships among them. The primary causes of the aphid problem are:

1. Untimely sowing.
2. Inefficient control by natural enemies.
3. Rapid aphid population build-up.
4. Irregular rainfall patterns.
5. Lack of aphid resistant or BCMV resistant varieties.
6. Inadequate research on aphids.

The final result of aphid and BCMV attack are weak and virus infected plants that yield poorly.

Figure 4. Causes and effect of high aphid infestation and damage and inter-relationships among them.



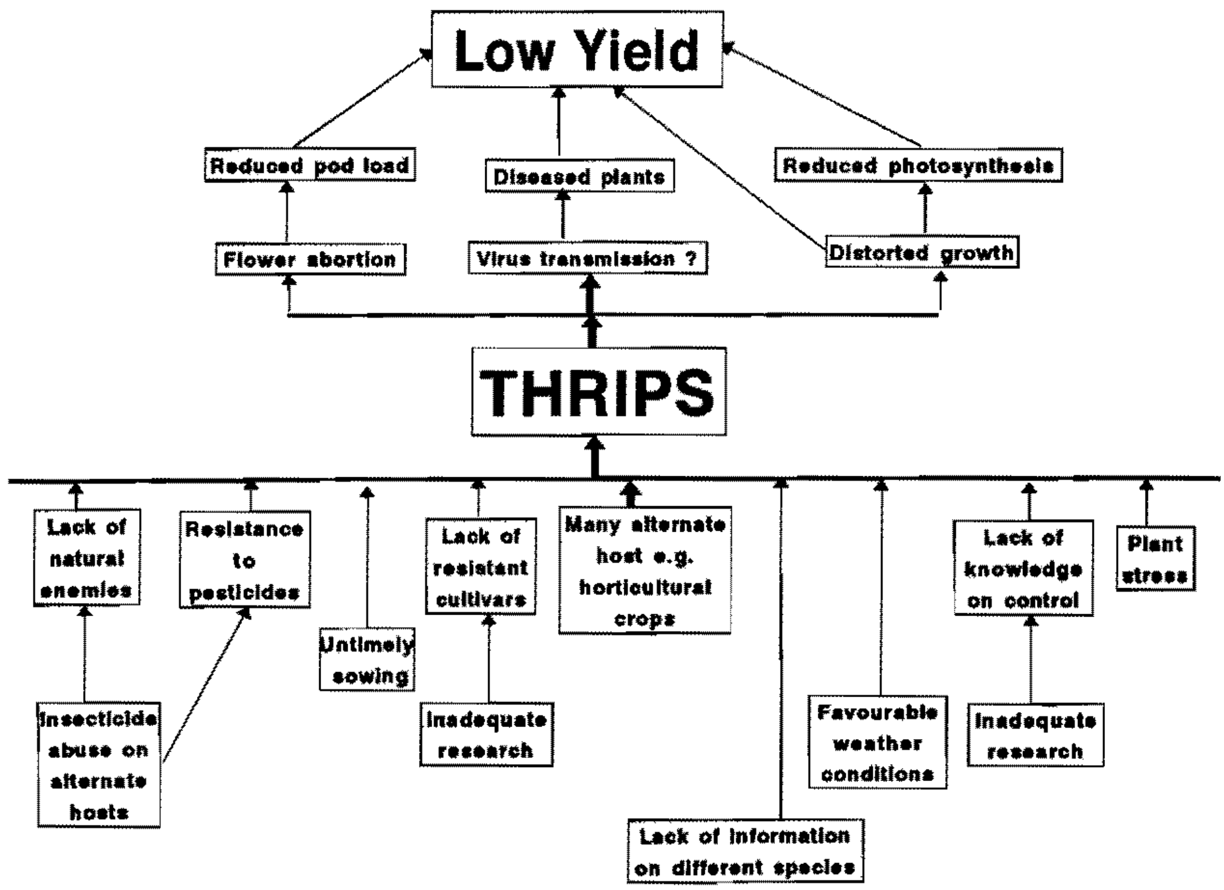
Thrips

Figure 5 shows the causes and effect of high thrips infestation and damage and inter-relationship among them. These include:

1. Insecticide abuse.
2. Inadequate pressure from natural enemies.
3. Abundance of alternate hosts.

Severe thrips infestation may be manifested by reduced photosynthesis (foliage thrips), flower abortion (flower thrips) and in some causes, virus transmission.

Figure 5. Causes and effect of high thrips infestation and damage and inter-relationships among them.



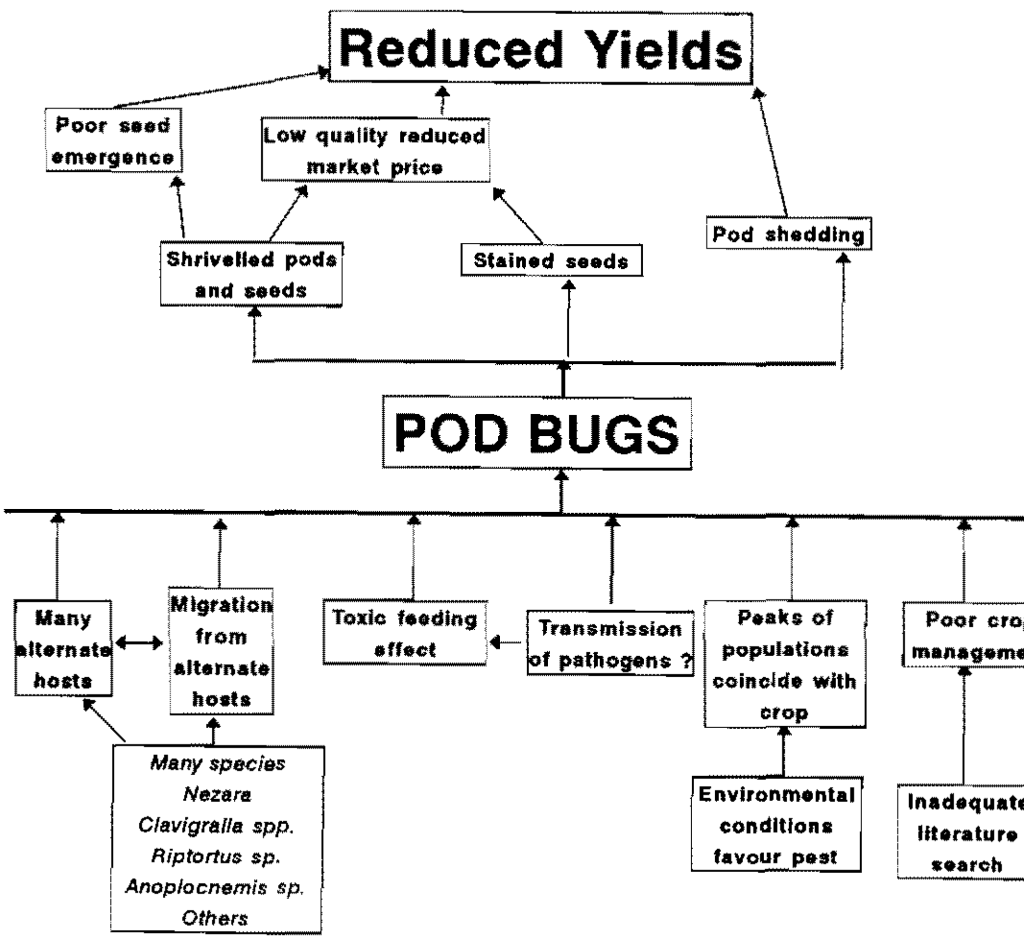
Pod bugs

Figures 6 shows the causes and effect of high pod bugs infestations and damage and inter-relationship among them. These include:

1. Abundance of alternate hosts.
2. The pest's ability to migrate.
3. Lack of resistant cultivars.
4. Poor crop management.

Pod bugs suck sap from developing pods and seeds and cause them to shrivel and or abort, surviving seed are stained. Pod bugs sometimes transmit fungal pathogens to pods that cause them to decay rapidly.

Figure 6. Causes and effect of high pod bug infestation and damage and inter-relationship among them.



IDENTIFICATION OF POTENTIAL SOLUTIONS AND PRIORITY SETTING AMONG THEM

Figures 1 - 6 illustrate the complexity of the causes and interactions between the different pest problems. They also suggest strategies for tackling the problems; for instance with BSM it is apparent that creation of farmer awareness through the publication and distribution of extension documents that educate farmers on the problem and how to manage it will help them deal with the BSM problem better. Development and distribution of BSM tolerant cultivars will enable farmers to extend the growing season of bean and allow the crop to be grown in areas that are otherwise considered as hot spots and therefore not used for bean production. A study of the causes and interactions between BSM and soil borne pathogens will lead to a better understanding of the synergism between the two problems and strategies to combat them. Similar analyses were made for the different pests identified (Tables 1 - 6) as key species that constrain bean productivity in the region. Each of the potential solutions was assessed as to whether or not they were researchable. Other considerations given to priority setting include:

i. The feasibility of conducting research in terms of resources and length of time required for research;
ii. Likelihood of research results being adopted by farmers;
iii. Magnitude of the expected impact (in terms of yield or economic returns).

These considerations were used to set priorities among the potential solutions.

IMPLEMENTATION STRATEGY: PROJECT DESIGN AND DOCUMENTATION

Tables 3 - 8 list possible solutions formulated into executable projects, the activities to be undertaken under these projects, verifiable indicators to assess the progress of the projects as well as the necessary assumptions for the success of the projects. Recommended projects include:

Table 3. Bean Stem Maggot: Setting priorities among potential solutions.

Potential Solutions (List)	Expected Output (Description)	Likelihood of Research Success (1-3)	Feasibility of Conducting Research		Likelihood of Farmer Adoption (1-3)	Magnitude of Expected Impact Yield/Cost (1-3)	Overall Priority (Rank)
			Resources (1-3)	Time (1-3)			
Create farmer awareness	Extension Manual	1	1	1	1	1 (1)	1 (1)
Technology transfer	- Farmer extension research trials - Technology adopted	2	1.5	2	2	1.5 (1)	1.8 (5)
IPM components	IPM components developed	1	1	1.5	1.5	1.5 (1)	1.3 (2)
Resistant varieties	Resistant varieties available	1.5	2	2	1	1 (1)	1.5 (3)
Studies on the interaction of BSM and soil borne pathogens.	Interactions better understood.	1	1.5	1.5	-	2.5 (2)	1.4 (3)

Table 3a. Implementation strategy for BSM management: Project planning matrices.

BSM Summary of Activities	Objectively verifiable Indicators	Means of Verification	Assumptions
Project Purpose:			
Reduce losses due to BSM	Improved plant stand and vigour	- On-farm observation - Reports	- Adaptability - Other constraints are under control
Output/Results: (Priority 1)			
Create farmers awareness/ extensionists	- Farmers aware of BSM damage and their occurrence in their fields	- Survey farmers' fields and interview farmers - Posters/Bulletin on BSM available	- Funds available - Extensionists + research collaborate - Farmers show interest
Activities:	Resources:		
- Produce posters and bulletin on BSM - Conduct farmers'seminar	- Entomologist and extensionists to develop bulletins and conduct seminars - Stationary	- Extension reports and research - Progress report	- Funds available - Entomologists and Extension collaborate
Project Purpose:			
Reduce losses due to BSM	- Improved plant stand and vigour	- Counts of plants - On-farm observation	- Adaptability, other constraints are under control
Output/Results: (Priority 2)			
IPM components developed	1. Reduced damage 2. Components accepted by farmers	Feed back from farmers and extension, observations on-farm	Availability of components (insecticides; ...)
Activities:	Resources:		
Develop components acceptable to farmers 1. To test acceptability of IPM components already identified 2. Demonstration and extension of accepted components.	1. Entomologist 2. Socio-Economist 3. Extensionist 4. Chemicals 5. Fertilizers	Survey Reports	Resources available

Table 3a. Cont.

BSM Summary of Objectives and Activities	IPM Components Objectively Verifiable Indicators	Means of Verification	Assumptions
Overall Goal:			
Increase yields	Increased yields/ha acreage	- Survey - Extensions Reports - National Statistics Reports	- Acceptability - Adaptability - Extension Service
Project Purpose:			
Reduce losses due to BSM	Improved plant stand and vigour	- On-farm observations	Adoptability other constraints are under control
Output/Results: (Priority 3)			
1. Resistant variety(ies)	Resistant varieties developed	Release of resistant varieties	A resources of resistance available
Activities:	Resources:		
1. Breeding for resistance 2. Breeding for BSM resistant cultivars.	Breeder Entomologist Sources of resistance, Funding.	Segregating populations available. Reports	Budget approved.

Table 3a. Cont.

BSM Summary of Objectives and Activities	IPM Components Objectively Verifiable Indicators	Means of Verification	Assumptions
Overall Goal:			
Increase Yields	- Yields/ha increases - Acreage under beans increases	- Survey - Extension Reports - National Statistics Reports	- Funding - Acceptability - Adaptability - Extension Services
Project Purpose:			
Reduce loss due to BSM	Improved plant stand and vigour	- Plant counts - On-farm observations	- Adaptability - Other constraints are under control
Output/Results: (Priority 4)			
Interaction better understood	- Plant stand and vigour - Yield improvement due to better control of BSM and soil borne pathogens.	- Field trials	Other soil contracts controlled or improved.
Activities	Resources		
Field trials under controlled conditions	- Entomologist - Pathologist	Sampling and examination	Funding
1. Resistant varieties and seed dressing 2. Identification of pathogen and BSM interactions.			

Table 3a. Contd.

BSM Summary of Activities	Objectively verifiable Indicators	Means of Verification	Assumptions
Project Purpose:			
Reduce losses due to BSM	Improved plant stand and vigour	- On-farm observation - Reports	- Adaptability - Other constraints are under control
Output/Results: (Priority 5)			
Technology transfer	- Farmers - Extension and research on-farm trials	- Extension reports - Farmers adopt technology - Research progress report	- Funds available - Farmers interested - Extension and research collaborate
Activities			
- On-farm variety demonstration	- Trials on-farmers' fields	- Survey on farmers' fields	- Funds available
- On-farm demonstration on control practices: - Mulching - Earthing-up - Timely sowing - Use of fertilizer/manure - Chemical seed treatment.	- Farmers practice the developed technology	- Research progress reports and extension reports	- Research and extension collaborate

Table 4. Bruchids: setting priorities among potential solutions.

Potential Solution	Expected Output (Describe)	Likelihood of Research Success (1-5)	Feasibility Conducting Research		Likelihood Farmer Adoption # x Area (1-5)	Magnitude of Expected Impact Yield Cost (1-5)	Overall Priority Rank (1-5)
			Resource (1-5)	Time (1-5)			
Bruchids Research:							
Spp. distribution	Improved knowledge	3	3	3	-	-	(3.0) 2
Incorporation of arceline gene in adapted background.	Adapted resistant varieties	1	1	2	2	3	(1.8) 1
Solar heating	Reduced storage loss (grain food)	1	1	1	3	3	(1.8) 2
On-farm evaluations: [1]							
Collaboration with extension officers and farmers							
Sieving	Reduced	1	2	2	3	2	(2.0)}
Sunning	Storage	1	2	2	1	1	(1.4)}
Oils seed	Loss	1	3	2	4	3	(2.6)}1
Ash		1	2	2	1	2	(1.6)}
Tumbling		1	3	2	4	4	(2.8)}

[1]In spite of this high ranking of some of the potential solution (under on-farm evaluations) it was considered useful to evaluate all in collaboration with farmers and extension officers. This solution was given a priority ranking of 1 i.e. to be undertaken with the resources currently available.

Table 4a. Implementation strategy for Bruchids management project planning matrices.

Summary of Objectives and Activities	Objectively Verifiable Indicators	Means of Verification	Assumptions
Overall Goal:			
Increased food availability.	More beans available per household.	Surveys of farms and markets. National Reports on Food Security.	Acceptability of technology for both seed and food grain storage.
Project Purpose:			
Reduce storage losses due to Bruchids	Less damage due to bruchids	Spot surveys, (on-farm markets)	Adaptability of technology.
Output/Results: (Priority 1)			
Dissemination of technology: sunning, sieving, ash, oils, tumbling	Technology available and used by farmers	Spot surveys, (on-farm/markets) reports.	- Acceptability of technology - Cost effectiveness - Effective collaboration with extensions.
Activities:	Resources:		
- On-farm evaluation of technologies	- Extensionists - Entomologist - Socio-economist - Farmers - Materials, transport, - Funds.	- Reports - Degree of utilization of technology	- Sufficient funds available - Effective FPR methods in place.

Table 4a. Cont.

Summary of Objectives and Activities	Objectively Verifiable Indicators	Means of Verification	Assumptions
Overall Goal:			
Increased food availability	More beans available per household	Market/on-farm survey	
Project Purpose:			
Reduced storage losses to bruchids.	Less damage and less due to bruchids	On-farm and market surveys	
Output/Results: (Priority 2a)			
Development of solar disinfestation technology	Solar disnifestation technology developed.	Research reports.	
Activities:	Resources:		
Improvement of solar disinfestation techniques	- Entomologist - Engineer - Equipment - Funds	Reports Appropriate Solar heater available	

Table 4a. Cont.

Summary of Objectives and Activities	Objectively Verifiable Indicators	Means of Verification	Assumptions
Overall Goal:			
Increased food availability	More beans available per household	Market/on-farm Survey-Report.	
Project Purpose:			
- Reduce storage losses due to *Zabrotes*	Less damage and less weight loss on beans	Survey (on-farm, market)	
Output/Results: (Priority 2b)			
- Incorporate resistance to adapted/local varieties of beans	Adapted varieties resistance	Research reports	
Activities:	Resources:		
- Breeding for resistance to *Zabrotes*	Breeders, Entomologists Funding	Reports, Segregating population available	Funding available from National Programmes
Project Purpose:			
Knowledge on spp. distribution	Species distribution mapped	Research reports	
Output/Results: (Priority 3)			
Determine spp. distribution for targeting breeding for *Zabrotes* resistant and IPM packages for *Acantholides*	Bruchids species distribution mapped	Reports	
Activities:	Resources:		
- Survey (Case Study)	Entomologists, Breeders Funding	Reports and Papers	Budget available and allocated.

Table 5. Ootheca: setting priorities among potential solutions.

Potential Solution (List)	Expected Output (Describe)	Likelihood Research Success (1-3)	Feasibility of Conducting Research		Likelihood of Farmer Adoption # x Area (1-3)	Magnitude of Expected Impact Yield/ Cost (1-3)	Overall Priority (Rank)
			Resources (1-3)	Time (1-3)			
<u>OOTHECA:</u>							
- Initiate research on: - Biology	- Knowledge of life cycle	1	1	1	-	1 (1)	1 (1)
- Study Ecology	- Environmental factors - Natural enemies - Population dynamics - Alternate hosts	1	1	2	-	1 (1)	1.25 (2)
- Develop Control	- Control strategies developed	1.5	2	2	1.5	1 (2)	1.6 (3)
- Farmer's management practices	- Practices Known	1	1	1	-	- (2)	1 (1)

Table 5a. Implementation strategy for *Ootheca* management: Project planning matrices.

Summary of Objectives and Activities	Objectively Verifiable Indicators	Means of Verification	Important Assumption
Overall Goal:			
Increase bean productivity.	Increased bean yields in farmers' fields.	- Surveys - Extension reports - National statistics report	- Research feasibility - Extension collaboration
Project Purpose:			
Study the biology of *Ootheca* species on beans	A better understanding of *Ootheca* biology	Progress Reports	Resources available
Output/Results: (Priority 1)			
- Improved knowledge of Ootheca species and their biology - Publications	- Literature searched - Biology studied - Progress reports written	Publications on *Ootheca* species and biology	Resources for research available
Activities:	Resources:		
Studies on *Ootheca* spp. composition and biology: - Oviposition sites - Larval feeding sites - Developmental cycle - Adult feeding behaviour.	- Entomologist - Laboratory and field facilities	- Progress reports - Knowledge used in development of control strategies.	

Table 5a. Cont.

Summary of Objectives and Activities	Objectively Verifiable Indicators	Means of Verification	Important Assumption
Overall Goal:			
Increase bean productivity.	Increased bean yields in farmers' fields.	- Surveys - Extension reports - National statistics report	- Research feasibility - Extension collaboration
Project Purpose:			
To study *Ootheca* spp. distribution and ecology	A better understanding of *Ootheca* spp. distribution and ecology	Progress Reports	Research Resources Available
Output/Results: (Priority 2)		Information on:	
- Improved knowledge on *Ootheca* ecology	Better understanding of *Ootheca* biology and ecology	1. Environmental factors and influencing populations build-up 2. Natural enemy complex 3. Key mortality factors 4. Alternate hosts 5. Species distribution map	- Entomologist - Collaboration from network - Project supported
Activities:	Resources:		
Studies on Ootheca spp. distribution and ecology	Entomologist Lab and field research facilities	- Publications - Knowledge used in development of control strategies.	- Budget approved - Project supported

Table 5a. Cont.

Summary of Objectives and Activities	Objectively Verifiable Indicators	Means of Verification	Important Assumptions
Overall Goal:			
Increase bean productivity.	Increased bean yields in farmers' fields.	- Surveys - Extension reports - National statistics reports - Publications	- Research feasibility - Extension feasibility
Project Purpose:			
Development of control practices to reduce losses due to *Ootheca*	Reduced *Ootheca* damage	- On spot survey - Research reports	
Output/Results: (Priority 3)			
Control strategies for *Ootheca* in farmers field	Less *Ootheca* damage in farmers' fields	Reports from extension + farmers	- Control strategies adoptable - Efficient extension system in place
Activities:	Resources:		
- Development of effective and sustainable *Ootheca* control strategies - Chemical - Cultural - Biological	- Entomologist - Social Scientist /Extensionist	- Progress Reports - Control Methods under evaluation in farmers' fields	- Entomologist in place - Budget approved - Funding available

Table 5a. Cont.

Summary of Objectives and Activities	Objectively Verifiable Indicators	Means of Verification	Important Assumptions
<u>Overall Goal:</u>			
Increase bean productivity.	Increased bean yields in farmers' fields.	- Surveys - Extension reports - National statistics reports - Publications	- Research feasibility - Extension feasibility
<u>Project Purpose:</u>			
To document farmer's management practices	A document on farmers' management practices	Progress Reports	Farmers deliberately control *Ootheca*
<u>Output/Results:</u> (Priority 4)			
Better knowledge of farmers' management practices for incorporation into an IPM package	Information on farmer management practices gained	Publication on farmers' management practices	Collaboration with extensionists
<u>Activities:</u>	<u>Resources:</u>		
- Surveys on farmers' management practices in different locations	- Transportation - Extension support	Publications	- Budget approved - Project supported

Table 6. Aphids: Setting priorities among potential solutions.

APHIDS AS DIRECT PESTS

Potential Solution (List)	Expected Output (Describe)	Likelihood of Research Success (1-3)	Feasibility of Conducting Research		Likelihood of Farmer Adoption # x Area (1-3)	Magnitude of Expected Impact Yield/ Cost (1-3)	Overall Priority Rank (1-5)
			Resources (1-3)	Time (1-3)			
APHIDS:							
As a Pest							
- Resistant varieties	Resistant varieties developed	2	2	3	1	3 [3]	1.8 [4]
- Development of IPM components	IPM components Development	2	2.5	2.5	2	1 [1]	2.0 [5]
- Population dynamics distribution	Ecology understood better	1.5	2	1.5	-	2 [3]	1.7 [3]
As a Vector							
- Use of sources of resistance in breeding programme	Resistant varieties developed	1	1.5	2.5	1	1 [1]	1.4 [1]
- BCMV potential aphids vectors: trapping of alates	Other aphid vectors of BCMV identified	1.5	1.5	1.5	-	1 [1]	1.5 [2]

Table 6a. Implementation strategy for Aphids management: Project planning matrices.

Summary of Objectives Activities	Objectively Verifiable indicators	Means of Verification	Assumptions
Project Purpose:			
To reduce losses due to BCMV	Plant vigour improved, reduced incidence of BCMV in fields	On- farm observations of BCMV free bean plants. Research reports	
Output/Results: (Priority 1)			
Resistant varieties to BCMV made available	Resistant varieties to BCMV developed	Release of BCMV resistant varieties. Progress reports.	Source of resistance available
Activities:	Resources:		
Breeding for resistance to BCMV.	Virologist Breeder Entomologist Sources of resistance, funding.	Segregating populations Progress report	Budget approved for research activities.
Project Purpose:			
Study potential aphid vectors of BCMV	Studies of other vectors of BCMV conducted	Progress report	
Output/Results: (Priority 2)			
- Potential BCMV aphid vectors identified - Aphid vectors of BCMV identified.	Other aphid vectors identified	Progress report	- Other aphids vectors are present in study areas - Resource personnel available
Activities:			
- Trapping winged aphids and identify species - Screen house testing - "Elisa testing"	Aphids vectors of BCMV trapped and identified	Progress report	- Resource personnel available - Collaboration with virologists and other institutes.

Table 6a. Contd.

Populations dynamics and distribution of aphids Summary of Objectives and activities	Objectively verifiable Indicators	Means of Verification	Assumptions
<u>Overall goal:</u>			
<u>Project Purpose:</u>			
To study the ecology of aphids on beans	Population Studies	A list of alternate hosts Population curves, natural enemies curves, Environmental factors identified.	No treatments on farmers' fields.
<u>Output/Results:</u> (Priority 3)			
Better understanding on Ecology of aphids on beans.	Monitoring of Populations	Research reports	Viable sampling method is available or developed
<u>Activities/Identification Monitoring</u> :	<u>Resources:</u>		
- Population studies - Trapping - Collection of samples	Entomologist Statistician, Funding	Reports and other publications	Funding available
Overall goal:			
<u>Project Purpose</u>:			
Reduce losses due to Aphids	Aphids damage reduced.	On-farm observations Research reports.	
<u>Output/Results</u>: (Priority 5)			
IPM Package	IPM Package developed	Progress reports.	
<u>Activities</u>:	<u>Resources</u>:		
Development and Implementation of IPM components	Funding Manpower	Report/Manual on IPM Package	Resources/Funding available

Table 7. Pod bugs: Setting priorities among potential solutions.

Potential Solution	Expected Output	Likelihood of Research Success	Feasiability of Research		Likeli-hood of Farmer Adoption # x Area	Magnitude of Expected Impact Yield cost	Overall Priority Rank (1-5)
			Resources	Time			
<u>POD BUGS</u>							
Literature Search	Increased knowledge	1	1	1	-	-	(1) 1
Development management practices IITA/ICRISAT	Suitable management practices	1	2	1	-	-	(1.3) 2
Evaluation of loss due pod bugs (on-farm)	Importance of pest outlined	1	3	2	-	-	(2.0) 3

Table 7a. Implementation strategy for pod bugs management: project planning matrices.

Summary of Objectives and Activities	Objectively Verifiable Indicators	Means of Verification	Assumptions
Project Purpose:			
- Reduce losses in yield, - Improve seed quality.	Better yields and seed quality	Field/market surveys. Progress reports	Other constraints controlled (pod borers, drought, soil fertility), adoption of generated technologies by farmers
Output/Results: (Priority 1)			
Literature search to increase knowledge	Literature review and analysis	Progress report	Availability of literature
Activity:	Resources:		
Initiate search through correspondence libraries, CD-ROM	Entomologist time, stationery, finance	Progress Reports of publications reviewed ?	Access to libraries and CD-ROM Published literature is available Response from colleagues.
Output/Results: (Priority 2)			
Information search on current recommended management practices for other legumes to increase knowledge	Compilation of management packages (in collaboration IITA, ICRISAT etc.)	Inventory management practices	Packages available Cooperation of other institutes compatibility
Activity:	Resources:		
Identify sources, compile information, consultations	Funding Time Personnel (Farming Systems Expert)	Progress Report	Cooperation etc.

Table 7a. Contd.

Summary of Objectives and Activities	Objectively Verifiable Indicators	Means of Verification	Assumptions
Project Purpose:			
- Reduce losses in yield, - Improve seed quality.	Better yields and seed quality	Field/market surveys. Progress reports	Other constraints controlled (pod borers, drought, soil fertility), adoption of generated technologies by farmers
Output/Results: (Priority 3)			
On-farm loss assessment to establish the magnitude of losses	Knowledge on the extent of field damage: (e.g - no. of pods punctured - seeds shriveled - seeds discolored - pod rot).	Report and Data Collected	Pod bugs trully causing loss Losses are measurable Losses occur on-farm
Activity	Resources		
On-farm trials yield and evaluations (protected and unprotected) Assess market value of damaged and good seed, and green pods	Farmers/land Insecticides Cages Socio-Economist's time Finance	Reports	Farmer participation Access to market

Table 8. Thrips: Setting prioritions among potential solutions.

Potential Solution	Expected Output (Describe)	Likelihood of Resource Success (1-3)	Feasibility of Conducting Research		Likelihood of Farmer Adoption Area (1-5)	Magnitude of expected Impact Yield on Cost (1-5)	Overall Priority rank (1-5)
			Resource (1-5)	Time (1-3)			
Thrips							
Literature Search	Improved knowledge of thrips ecology and damage.	1	1	1	-	-	(1) 1
Surveys to gain better understanding of thrips ecology and control	Species - Identification - Distribution - Damage overview in "Hot Spots"	2	3	3	-	-	(2.7) 1
Damage Assessment	Yield /infestation Relationships	3	2	3	-	-	(2.7) 2

Table 8a. Implementation strategy for thrips management: Project planning matrices.

Thrips: Assessment of infestation and damage patterns.

Summary of Objectives and Activities	Objectively Verifiable Indicators	Means of Verification	Assumptions
Project purpose			
Determine the yield/thrips infesttion relationships.	Surveys and field trials.	Progress reports	
Output Result: (Priority 1)			
1. Yield/infestation relationships established	Trials established at various locations (farmers fields and research stations)	Progress reports Workshop Reports	
Activities:	Resources:		
1. Damage assessment trials 2. Develop methodology (sampling etc...) Testing/adopting	Entomologists and support Training Equipment and materials	Damage estimates available and Reports	

Table 8a. Contd.

Summary of Objectives and Activities	Objectively Verifiable Indicators	Means of Verification	Assumptions
Project Purpose:			
Identify thrips species that damage beans.	Manual on a simple key to species determination of thrips on beans.	The publication	Funding available
Output/results: (Priority 2)			
1. Species Identified 2. Distribution 3. Damage Overview 4. Alternate host known	National programmes contacted methodology for surveys developed	Progress reports	Taxonomist Available Good Communication Support to National Programme
Activities:	Resources:		
Surveys prepared work programme collected and send samples to IITA.	National Programme Entomologists support Staff	Survey Reports and Summaries Progress Reports	
Project Purpose:			
Assess importance of thrips	Species composition distribution and damage	Survey Reports	
Output/Results: (Priority 3)			
Improved Knowledge	Literature searched	Recommendations for Action	Appropriate into available

ANNEX I

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ANNEX II

SECOND MEETING OF THE PAN-AFRICA WORKING GROUP ON BEAN ENTOMOLOGY HARARE, ZIMBABWE 19-22 September 1993

PROGRAMME

Sunday September 19: Registration.

Day 1: Monday September 20

08:00 - 09:00 **Session 1** **Denash Giga/Simon Slumpa**

Opening.
Introductions.
Objectives of meeting/discussion and adoption of the proposed programme.

09:00 - 12:30 **Session 2** **Greenwell Nyirenda/Gareth Davies**

Sub-project reports and new proposals.

12:30 - 14:00 **Lunch**

14:00 - 15:30 **Session 3** **Wayne Youngquist/Macharia Gethi**

General discussions on sub-project reports and new proposals.

- Aphids.
- Bean Stem Maggots.
- Bruchids.
- *Ootheca.*
- Etc.
- Species distribution.
- Bruchids - Extent of use of various products by farmers. If low why ?
- Training - across bound.
- Farmer involvement.

16:00 - 17:30 **Session 4 (IPM)** **Clemence Mushi**

- IPM development and practice in Mauritius.
- Snap bean IPM in Kenya: A proposal and some initial results.
- General discussion on IPM.

Day 2: Tuesday September 21

08:00 - 17:00 **Session 5** **Jeff Mutimba**

Priority setting among constraints, planning of research activities within the entomology network.

18:00 - 20:00 **Barbeque Dinner**

Day 3: Wednesday September 22

08:00 - 12:30 **Session 5 Cont.**

12:30 - 14:00 **Lunch**

14:00 - 17:00 **Session 6** **Kwasi Ampofo/David Kabungo**

General discussion and adoption of recommendations on priorities, plans and strategies.

Any other business.

Closing.

Day 4: Thursday September 23

Departure.