SESSION 5
INTEGRATED PEST AND DISEASE MANAGEMENT (IPDM)

RESEARCH ON BEAN ROOT ROT IN KENYA

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ABSTRACT

This paper summarises the research findings of recent studies on bean root rot in Kenya, where bean production has been constrained by root-rot disease. These studies have covered the etiology and epidemiology of bean root rot, interactions of the root-rot pathogen with soil-borne insects (such as the bean stem maggot), and the relationship between the root-rot pathogen and soil fertility and the moisture content of the soil. In addition, an integrated strategy to control bean root rot has been developed. Future work on the study of the genetics and inheritance of plant resistance to the root-rot pathogen is indicated.

RÉSUMÉ

Le présent document récapitule les résultats des recherches d'études récentes entreprises sur le pourridié du haricot au Kenya où cette maladie entrave la production. Les études ont porté sur l'étiologie et l'épidémiologie du pourridié du haricot et sur les interactions entre l'agent pathogène et les insectes terricoles (comme la mouche du haricot), et le lien entre l'agent pathogène du pourridié et la fertilité du sol ainsi que son taux d'humidité. Une stratégie intégrée de lutte contre le pourridié a également été élaborée. Ce document indique aussi le travail futur portant sur l'étude de la génétique et de l'hérédité de la résistance végétale à l'agent pathogène du pourridié.

Key words: Phaseolus vulgaris*, resistance, bean root rot, soil fertility, integrated disease management, genetics of inheritance.*

INTRODUCTION

Beans (*Phaseolus vulgaris*) are the most important leguminous crop in Kenya and the leading source of dietary protein, (Gitu, 1992; Otsyula et al., 1993). Recently, bean production has been declining in western Kenya (Otsyula, 1994). This is associated with bean root-rot disease caused by a complex of soil-borne fungi, a problem that has been increasing in importance in Africa (CIAT, 1990, 1992, 1993a; Abawi and Pastor-Corrales, 1990). In Central Africa, especially Rwanda, bean root rot became important as early as 1990 (Buruchara and Rusuku, 1992), when it was still ranked low in terms of constraining bean production in Kenya.

Increasing demographic pressure has led to the shortening of fallow periods and continuous cultivation without crop rotation. This system results in a decline in soil fertility and high disease inoculum in the soil (Otsyula, Nderitu, and Rachier, 1998)—the major factors linked with the severity of bean root rot (Buruchara and Rusuku, 1992). Low production, non-existent periods of fallow, low fertiliser inputs, and general use of susceptible bean varieties characterise the areas where bean root rot is a problem.

In western Kenya, bean root rot is primarily caused by *Fusarium solani* spp., *Phaseoli*, *Rhizoctonia solani*, *Sclerotium*, and *Pythium* spp. (Otsyula, 1998), which occur in a complex in the soil and may attack the same plant, causing specific symptoms. They live in the soil and attack the tender root system, often penetrating through the porous root region. *Pythium* causes damping off in young seedlings; the taproot of the affected plant shows lesions and whitish mycelia. *Sclerotium* is recognised by gray water-soaked lesions, which later become brown and extend downwards to the taproot, leading to wilting. *Rhizoctonia* has a reddish brown, sunken canker with clearly defined boarders. *Fusarium* is recognised as narrow, longitudinal, reddish brown streaks on the hypocotyl and taproot.

Studies have shown that root rots became severe in areas where bean stem maggot occurs (Nderitu et al., 1996). This is because the root-rot pathogens gain easy entry through the root damage caused by the bean

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stem maggot. Field beans (*P. vulgaris*) are the main host of the bean root-rot pathogens. In western Kenya, root rot is often absent on other common legumes like cowpeas, soybeans, *Dolichos lablab*, *Mucuna*, *Crotolaria*, etc. The pathogens are not internally seed borne but may be carried on contaminated seed, in which case the inoculum levels are often low and disease may not occur.

The pathogens for bean root rot survive in the soil indefinitely in different forms: *Fusarium* as a chlamydoyspore, *Sclerotium rolfsii* and *Rhizoctonia solani* as *sclerotia*, and *Phythium* as oögonia. The general field symptoms are damping off at the seedling stage, yellowing of the leaves, stunted growth, and death in severe cases (Otsyula and Ajanga, 1994; Otsyula et al., 1998). There is sometimes complete crop loss in severely infested fields.

CONTROL AND PREVENTION

The ability of bean crops to tolerate root rot is related to the level of soil nutrients, so prevention is effective in environments where soil fertility is good (Otsyula and Ajanga, 1994). Keeping the inoculum level low could also effectively control the disease. This is usually possible in systems where crop rotation is practiced and resistant bean varieties are used (Hall and Phillips, 1992), but in western Kenya, beans are a major food crop and small-scale farmers are reluctant to decrease the frequency of sowing beans on a small piece of land (Otsyula et al., 1998), which makes it difficult to use crop rotation as a practical measure for reducing soil contamination.

Using available information on managing bean root rot, the Regional Research Centre Kakamega, in collaboration with the International Centre for Tropical Agriculture (CIAT), initiated an adaptive research program in 1993 to develop alternatives for integrated management of root rot. The objectives were to identify resistant or tolerant genotypes that were acceptable to farmers and consumers, to evaluate the effectiveness of different cultural practices in the control of root and rot complex, and to study other biotic and abiotic factors that affect the root rot complex.

Cultural methods

Planting on ridges

Planting beans on ridges can be effective in reducing the severity of root rot where soils are not well aerated (Pieczark and Abawi, 1978; Miller and Burke, 1985; Buruchara, 1991; Buruchara and Rusuku, 1992). Hilling up soil around the stem of seedlings encourages the growth of adventitious roots, resulting in tolerance to the disease (expressed as the ability of the plant to recover from attack). Beans were planted on ridges in the Vihiga district of western Kenya to determine the effects on plant mortality from root rot. Results showed that plant mortality was reduced by 70%, with a 20% yield gain (which was lower than when DAP was used, probably because the plants need nutrients for higher production). Planting on ridges is most effective when it is integrated with soil fertility management. It is labour intensive, especially in systems where beans are traditionally not planted on ridges.

Clean seed

Certified seed of a susceptible variety, assumed to be clean and free from root rot inoculum, was planted in hot spots. This was to investigate the possibility that the severity observed in farmers' fields was due to contaminated seed used by farmers. Farmers are known to use seed from their own fields for several planting seasons, which leads to seed contamination, especially by seed-borne pathogens. The results showed that clean seed did not reduce the severity of the disease (Otsyula et al., 1998). It was further evident that the pathogens were not seed borne.

Use of inorganic fertiliser

Fertiliser is known to improve tolerance to bean root rot (Mutitu et al., 1985; CIAT, 1992). DAP (at the rate of 150 kg/ha), TSP (150 kg/ha), urea (87 kg/ha), and KCl (160 kg/ha) were tested against a control in a series of experiments to study their effect on bean root rot. DAP and TSP were effective in improving crop tolerance by lowering plant mortality, encouraging growth of adventitious roots, and improving grain yield. Nitrogen, provided through urea, and potassium, provided through KCl, did not have any effect on control of bean root rot (Otsyula, 1998). An adequate supply of soil nutrients is an important factor in a crop’s tolerance to root rot. Otsyula and Ajanga (1994) reported that a high nutrient supply increased growth vigour and resulted in enhancement of plant tolerance to root rot. However, inorganic fertilisers are expensive and not within the reach of resource-poor farmers who form the majority of bean growers.

Use of organic manure
Organic matter forms an important part of the bean-growing environment in the soil. Addition of organic matter to the soil may bring about microbial changes that affect the dynamics of root-rot pathogens (Wortman, C.S. 1994) either through an attack on the pathogen by soil micro-organisms or competition for same essential substrate (Papavisas and Davey, 1960). Green manures (*Sesbania sesban*, *Leuceuna*, *Calliandra*, *Tithonia diversifolia,* and *Clotolaria*), farmyard manure, and compost were tried in a series of experiments to determine their effectiveness in controlling bean root rot. Recommended rates of 10 tons of manure per hectare were used to compare the manures with the control. It was found that crop tolerance was improved by the application of green manures. Plant mortality was reduced by over 40% and yield increased by 50%. The major limitation was availability (Otsyula and Ajanga, 1997; Otsyula et al., 1997; Otsyula and Nderitu, 1998). The recommended rate of 10 ton/ha was high for small-scale farmers. Farmers were encouraged to produce green manures in situ on their farms, but this was not popular as the manure competes against food crops.

Herbaceous legumes (*Mucuna, Dolichos lab lab, Crotalaria* spp., and *Canavalia*), were introduced as short fallow rotations with maize/bean intercrop or relay crops in the maize. These were meant to maximise space while producing large amounts of manure that could easily be incorporated into the soil during land preparation. The results showed that the herbaceous legumes effectively increased bean yields and at the same time, reduced the severity of the root rot (Otsyula and Ajanga, 1998). Farmers, however, still considered this system as inappropriate because they were losing one season where maize and beans or beans would have been grown.

Cattle manure is commonly found on farmers' fields in western Kenya. Other minor sources of manure are poultry, sheep, and goats. Cattle manure is collected mainly from zero-grazing units, but the amounts are limited due to the small numbers of cattle, resulting in low rates of manure being applied to the fields. The commonly applied rate in the maize/bean fields is one handful of manure per maize hole (2.5 ton/ha). Acland (1986:20–25) recommended of farmyard manure 10 ton/ha for maize, with a minimum recommended rate applied in maize holes of 5 ton/ha (Otsyula and Nderitu, 1998). Farmers either apply the manure directly, pile it up in one spot, or make compost for later use. Farmers tend not to realise the full potential of manure because of poor handling, storage, and application.

Combinations of organic and inorganic manure
Investigation of the combined effects of different organic and inorganic manures on bean root rot severity was done in western Kenya (Otsyula and Ajanga, 1998). The objectives were to determine the effect of inorganic/organic fertiliser on root rot and to assess the socio-economic acceptability of organic and inorganic sources of phosphorus (P). The treatments compared were application of phosphorus (TSP) 25 kg/ha as P_2O_5, *Tithonia* at the rate of 5 tons dry matter per hectare, phosphorus (TSP) applied at 12.5 kg/ha, P_2O_5 + *Tithonia* at 5 ton/ha, *Tithonia* applied at 10 ton/ha, and a control where no soil amendment was used. Results showed that *Tithonia* applied at the rate of 10 ton/ha gave a yield increase of 700 kg/ha and *Tithonia* applied at 5 tons per hectare in combination with a half rate of DAP (75 kg) gave 400 kg over the control. This was the same as when *Tithonia* was applied at 5 tons in combination with half the recommended rate of TSP (25 kg of P_2O_5). There were no significant differences between the various soil treatments on plant survival but all were better than the control—all resulted in better plant survival and yield increase. Farmers preferred the combinations because they were cost effective.

Time of planting
A participatory rural analysis was conducted in Vihiga division in 1996 to identify and diagnose bean root rot. It was found that farmers were able to identify the root-rot problem in their fields, but they attributed it to such factors as witchcraft, dry spells, high rainfall, early planting, and late planting (Nderitu and Otsyula, 1997). The extension and research were unable to differentiate the effects of bean root rot and bean stem maggot where both constraints occurred especially in late planted crop. Trials on effects of planting time, severity of bean root rot and bean stem maggot were conducted in 1997 (Otsyula and Nderitu, 1997). Data showed no direct correlation between time of planting and the severity of the root rot. *Phythium* tended to occur on crops grown when there was high rainfall in a season, while the severity of *Rhizoctonia*, *Sclerotium,* and *Fusarium* did not depend on the moisture status of the soil. This may be because the *Phythium* oöspores require soil water to swim to infection sites. The incidence of bean stem maggot (BSM) was higher on crops grown four weeks after the onset of rain, but the moisture content in the soil did not affect the severity of BSM infestation, which may have been related to the time needed for the insect population to build up. The conclusion was that planting time cannot be used to prevent bean root rot.

Chemical control
Seed treatment with a fungicide (Benlate) was tried in experiments at Regional Research Centre Kakamega. Benlate (28 g per kilo seed per hectare) was used before planting on a susceptible variety GLP-2. Plant survival—used as a measure of severity in the experiments—was reduced by over 90%. Taproot lesion scores were no different from the control (100%) (Otsyula and Ajanga, 1994; Otsyula and Nderitu, 1995). The fungicide is specific for a fungal species and the time it occurs in the field (Eric et al., 1997), but where the pathogen occurs in a complex, a single fungicide might not be effective. This could be why Benlate was not effective in this experiment.

Plant host resistance

Selection of resistant varieties
Breeding for disease resistance has been identified as the main hope for controlling diseases in resource-poor developing countries. Bean varieties have shown host plant resistance to several fungal pathogens, but in Africa, since bean root rot was not severe in the past, sources of resistance were not identified early on. GLP-2, GLP-24, GLP-1004, GLP-585, and GLP-X92 were released in Kenya in the seventies when bean root rot was not a disease of any economic importance, and none of these varieties have resistance to the disease.

In 1992, CIAT-Rwanda initiated a series of screening trials to identify sources of the root-rot complex. The regional bean root-rot nursery was constituted with materials contributed from Rwanda, Burundi, Zaire, and Uganda. These programs were screening bean germplasm against different constraints such as acidic soils, leaf diseases, angular leaf spot, common bean mosaic virus and rust, and bean stem maggot. Twenty-six entries suitable for areas infested with root rot were identified from the regional nursery (table 1) and introduced in Kenya in 1993 short rains. They were tested alongside 374 collections from the Kenya germplasm core collection in root-rot hot spots (Otsyula et al., 1994)—screened for resistance and tolerance based on root-rot rating and bean yield. Ratings were percent of hypocotyl with visible lesions below ground level. Results identified 10 resistant lines (10% of taproot covered with lesions) and six tolerant ones (10%–30% of taproot covered with lesions) from the original 400 entries after two seasons of evaluation (Otsyula et al., 1994; 1998). Of the 374 local accessions, only GLP-X92 was found tolerant. Many introductions found to be resistant to root rot in Rwanda were also found to be resistant in Kenya. Resistant types represented a wide range of seed colour, growth habit, and time to maturity (table 1).

Farmer participatory evaluation of root-rot resistant varieties
Ten resistant varieties—nine introductions and one local variety (GLP-X92)—were given to farmers for on-farm farmer evaluation and selection. RWR-1059 was not included in farmer evaluations because of its lower yield potential, yielding less than the local check (GLP-X92) in trials. Farmer evaluations were participatory, involving 30 farmers the in Vokoli sub-location of Vihiga District. The objective of the evaluation was to expose the farmers to a large number of resistant varieties and at the same time generate information about the varieties that could help in making future decisions. Farmers were requested to evaluate the varieties from 1995 to 1998, based on their own criteria. Farmer evaluations were done in the 1998 long rain by extension agents, researchers, and NGOs. Farmers ranked their selection criteria in the following order: high yield, resistant to bean root rot, maturity period, market price, seed taste, cooking time, seed colour, and seed size (table 2).

Scam-80cm/15 was the most preferred by farmers and best for market, followed by MLB49-89A, RWR-719, and RWR-1092. Red haricot types are popular in the local markets, and farmers identified RWR-719 as a perfect substitution for the susceptible red haricot GLP 585. Farmers pointed out, however, that the variety is late maturing, which is a disadvantage, especially in hunger-prone areas. MLB49-89, though black in seed colour, thrilled farmers because of its early maturity, large seed size, ease in cooking, good taste, and high yield—all of which are very important for resource-poor subsistence farmers.

Selected bean varieties were multiplied and seed distributed to other parts of Kenya, notably the southwestern highlands of Kisii, central highlands-Embu area, and north Rift-Trans Nzoia District. Within western Kenya, seed was distributed to extension services and NGOs working in the area. Other projects have used the information from farmer evaluations to distribute suitable varieties to farmers, such as Farm Level Applied Research in East and Southern Africa (FARMESA) in the Ileho Division and the African Highlands Initiative (AHI) in the Emuhaya Division of western Kenya (Otsyula et al., 2000; Otsyula, 1999). It is estimated that over 5,000 farmers in western Kenya have received the seed of the new root-rot resistant bean varieties, which have been widely adopted. An impact study is underway to determine the effect of the new bean varieties on the resource-poor people of western Kenya (Odendo et al., 2001).

Table 1. Reaction to Bean Root Rot of 26 Bean Introductions from the Regional Root-Rot Nursery

	Name	Colour	Maturation	RX.BRR*
1.	IHUMURE	Grey	Medium	R
2.	MCD 221	Rose coco type	Medium	S
3.	36-89A	Zebra	Medium	S
4.	PEVEYA	Rose coco type	Medium	S
5.	MLB-22-88B	Rose coco type	Medium	T
6.	MLB-69-88A	Zebra	Medium	S
7.	MLB-17-89A	Rose coco type	Early	S
8.	SCAM-80-CM5	Rose coco type	Early	R
9.	SCAM-80-CM15	Rose coco type	Early	T
10.	MLB-48-89A	Grey (small)	Late	R
11.	RWR-1058	Rose coco type (small)	Medium	T
12.	RWR-1059	Rose coco type (small)	Early	R
13.	MLB-39-89B	Chocolate yellow	Medium	R
14.	MLB-40-89A	Chocolate yellow	Late	R
15.	MLB-49-89A	Black	Early	R
16.	MLB-10-89B	Rose coco type	Medium	T
17.	MORE-90019	GLP X92 type	Medium	S
18.	A - 300	Grey (small)	Late	T
19.	RWR-1091	Rose coco type	Medium	T
20.	RWR-1092	Canadian Wonder type	Early	R
21.	RWR-432	Rose coco type	Medium	R
22.	RWR-719	Red haricot type	Late	R
23.	RWR-866	Rose coco type	Medium	S
24.	RWR-221	Grey	Medium	S
25.	RWR-217	Canadian type	Early	S
26.	URUGEZI	Canadian Wonder type	Early	S

* RX.BRR = Reaction to bean root rot: R= Resistant, T= Tolerant, S = Susceptible.

Breeding for resistance to multiple constraints: bean root rot, bean stem maggot, and low soil phosphorus

The complex of bean root rot, BSM, and low soil phosphorus (LP) has been identified as the main constraint to bean production in western Kenya (Otsyula, 1995). Known to occur under same the conditions in farmers' fields, BSM, root rot, and problems with low soil fertility are magnified by the intensification of bean production in high-population areas of the African highlands (Letourneau, 1994; Pachico, 1993). Independent studies have shown that there is sufficient varietal variability to be used for selection of resistance to this complex (Otsyula et al., 1998), but this variability has been identified independently. A screening nursery was established in western Kenya to identify bean varieties resistant to multiple stresses for control of bean root rot and BSM adapted to the conditions of low soil fertility in the region. Ten varieties were contributed from each stress nursery (root rot, BSM, and LP) and were used to constitute a nursery for multiple stress resistance. Preliminary data indicated that RWR-719, MLB-49-89A, MLB-48- 89A, and RWR-1092 from the root-rot resistant source were also resistant to BSM and LP. EXL-158 (resistant to BSM) was also resistant to LP and root rot, while RWK-5, known to be adapted under LP conditions, had good resistance levels to BSM and root rot. MLB-40-89A and XAN-97 showed reasonable tolerance when subjected to all stresses (Otsyula et al., 1998).

Table 2. Farmer's Varietal Selection and Selection Criteria for High-Yielding Root-Rot Resistant Bean Varieties

Criteria	Varieties									
	Ihumure	Scam 80cm/15	MLB-48-89A	RWR-1059	MLB-40-89A	MLB-49-89A	RWR-1092	RWR-432	RWR-719	GLP-X92
Yield 8	1	8	1	6	7	9	4	5	10	3
BRR 7	6	8	4	6	10	2	2	4	10	1
Maturity 6	5	3	3	5	1	9	9	5	2	9
Market 5	1	7	7	7	4	2	5	7	6	2
Taste 4	1	7	2	2	8	10	2	2	8	1
Cooking time 3	1	7	1	7	3	9	6	3	3	10
Colour 2	2	6	6	6	4	1	5	6	5	3
Size 1	1	7	5	5	2	9	9	7	2	4
Total	18	53	29	34	39	51	42	39	46	33
Rank	10	1	9	7	5	2	4	5	3	8

Introduction of climbing beans

Climbing beans were introduced in Kenya for several reasons: climbers are tolerant to root rot, have high yield potential (Otsyula et al., 1994), and need less space because of their climbing growth and efficient use of scarce resources, e.g., compost, farmyard manure, and green manure. When grown on small plots, climbing beans yield as much as 100 pods per plant. Six climbing bean varieties (Umbano, Flora, Gwinurare, Puebla, Vuninkingi, and Gisenyi) were introduced in western Kenya and evaluated for performance and acceptability in a predominantly maize-based system. They were found to be suitable for the highlands of Kenya. Umbano was recorded as yielding 4 t/ha (Otsyula et al., 1994). While preliminary evaluation of adoption indicated that climbing beans are favourable for small-scale farms (Otsyula, 1995), most farmers indicated that staking is a major constraint with climbing beans.

Integrated Control for Bean Root Rot

The selection and integration of control measures depend on the combination of opportunities available, the economic status of the farmer, and access to resources. Several experiments have been conducted to identify suitable combinations of technology for integrated control of bean root rot. Otsyula, Nderitu, and Rachier (1998) demonstrated that the most effective way to control bean root rot was with a combination of resistance and soil improvements. The use of green manure and farmyard manure enhanced crop tolerance to root rot. Improving soil fertility and using resistant varieties will reduce the pathogen inoculum in the soil while maintaining natural resources. The limitation is that resource-poor farmers often depend only on the easily affordable technology, which, in this case, is resistant varieties.

CONCLUSION

There are methodologies in Kenya for the control and management root-rot disease in beans. Cultural controls have been well researched and different options recommended to farmers. Sources of resistance have been identified and some varieties adopted by farmers. These recommendations may, however, need further refinement. Incorporating resistance in the existing market classes (GLP 2, GLP 585, and GLP24) is necessary to keep farmers' production market oriented. Technologies like marker-assisted selection for the transfer of resistant genes to market classes is recommended.

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ASSESSMENT OF GRAIN YIELD LOSSES CAUSED BY FOLIAR FUNGAL AND BACTERIAL DISEASES IN PROMISING NEW GENOTYPES OF THE COMMON BEAN IN MALAWI

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ABSTRACT

This paper looks at data obtained from trials to assess grain yield losses caused by foliar fungal and bacterial diseases in the common bean. These trials were conducted in Malawi in 1998/99 and 1999/2000 and showed that most of the promising new bean genotypes were suitable for production by the farming community. Control of foliar fungal diseases, such as angular leaf spot (ALS) with chlorothalonil, led to higher increases in grain yield than the control of foliar bacterial disease, such as common bacterial blight (CBB). The judicious use of chlorothalonil could be an important option in production strategies for the common bean, especially in areas like Bembeke, where foliar fungal diseases such as ALS are a serious problem in every cropping season. Common-bean genotypes like LSA 191 have consistently produced low scores for CBB at Bembeke, indicating that this genotype could be resistant and therefore a suitable candidate for developing integrated disease management (IDM) strategies for control of CBB and also for use in breeding programmes. More efforts need to be devoted to the development of new common-bean genotypes that would be suitable for incorporation in IDM strategies for the control of CBB, which drastically reduces yields and is considered the most important disease of the common bean in Malawi.

RÉSUMÉ

Le présent document examine les données obtenues à partir des expérimentations destinées à évaluer les pertes de rendement des graines provoquées par les maladies foliaires fongiques et bactériennes du haricot commun. Ces essais ont été effectués au Malawi au cours des années 1998-1999 et 1999-2000 et ont montré que la plupart des nouveaux génotypes prometteurs de haricots étaient adaptés à la production dans le cadre des communautés agricoles. L'utilisation du chlorothalonil semblait avoir de meilleurs résultats concernant le rendement dans le cas de la lutte contre les maladies fongiques foliaires telles que les taches anguleuses du haricot, que dans le cas des maladies bactériennes foliaires comme les brûlures bactériennes communes (BBC). L'usage judicieux du chlorothalonil pourrait représenter une option importante dans les stratégies de production du haricot commun, tout particulièrement dans des régions comme celle de Bembeke où des maladies fongiques (taches anguleuses) représentent un grave problème à chaque nouvelle saison de culture. Des génotypes du haricot commun tel que LSA 191 ont montré de façon constante à Bembeke un faible taux de contamination par les brûlures bactériennes, indiquant que ce génotype peut être résistant et constituer donc un candidat approprié pour la mise en place de stratégies de lutte intégrée contre les BBC ainsi que dans le cadre de programmes de sélection. Il faudrait pouvoir fournir davantage d'efforts afin de développer de nouveaux génotypes du haricot commun susceptibles d'être incorporés dans la lutte contre les brûlures bactériennes communes, une des maladies les plus importantes du haricot commun au Malawi limitant considérablement le rendement.

INTRODUCTION

Common beans (*Phaseolus vulgaris* L.) are adversely affected by numerous biotic and abiotic stresses that result in drastic yield losses. Diseases are one of the important biotic constraints that attack common beans in Malawi (Chitedze Agricultural Research Station, 1996, 1997, 1998). The severity of a particular disease on bean plants depends on the environmental conditions during the growing season. Under conditions favourable for a particular plant disease, even insignificant diseases can attain epiphytotic proportions. The occurrence of plant diseases under natural field conditions provides an opportunity to screen the germplasm of common beans and breeding materials for resistance to the diseases (Chitedze Agricultural Research Station, 1998).

The diseases of importance in the common bean in Malawi are angular leaf spot (ALS) and common

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bacterial blight (CBB). ALS is the most widespread disease in the bean-growing areas of Malawi and other parts of Africa. Different races of the pathogen are known to occur in Africa. For example, the common bean variety Napilira (CAL 143) was found to be resistant to ALS in Malawi but susceptible in Uganda, and some variation in the ALS pathogen has been observed on Napilira grown in multi-locational trials in Malawi (Anon, 1996, 1997, 1998). CBB is prevalent on common beans in all the crop-growing areas in Malawi. This disease is the most difficult to control because there are no bean varieties in Malawi known to have resistance or tolerance to CBB. Some common bean materials that have been screened in Malawi for resistance to CBB only have a partial or low level of resistance, except for the newly tested VAX lines, and even these results need to be verified (Anon., 1997, 1998). Attempts to control CBB with chemicals have failed to produce conclusive results (Anon., 1996, 1997, 1998).

It is thought that using strategies for integrated disease management (IDM) of all diseases attacking the common bean in Malawi (particularly ALS and CBB) would be a sound approach.

One of the main objectives of the Common Beans Pathology Research Programme is to aid breeders in improving germplasm. The breeders of common beans continuously develop new genotypes, which need to be screened efficiently so that materials released for cultivation in the country are suitable for production under the environmental conditions prevalent in the major bean-production areas.

The objectives of the Common Beans Pathology Research Programme in Malawi are as follows:

1. to continue the rigorous screening of promising new common-bean genotypes for resistance or tolerance to the major diseases in Malawi
2. to assess the grain yield losses caused by foliar fungal diseases in these promising new genotypes
3. to assess the grain yield losses caused by foliar bacterial diseases in these promising new genotypes
4. to develop IDM strategies for the increased production of common beans in Malawi

MATERIALS AND METHODS

The trial was run at Chitedze under a warm environment favourable for CBB on common beans. Bembeke was chosen to be a second site for this trial because of its cool environment, where ALS is a serious problem. The trial was laid out in a split-plot design where the promising new common-bean genotypes were the nine main plots.

The genotypes were Sapelekedwa and Nasaka (maintained as controls); Maluwa (CAL 113) and Sapatsika (DRK 57) (tested for the third season, which was also the final season of screening for these two newly released genotypes); Mlama 127, Rao 55, LSA 191, and EST 10 (screened for the second season, EST 10 was included as a third susceptible genotype after Sapalekedwa and Nasaka); and AFR 619 (screened for the first season in 1999/2000).

The sub-plots consisted of four rows, four metres long, replicated four times. The sub-plots comprised of two chemical treatments (chlorothalonil and copper hydroxide) and the untreated control. Chlorothalonil—a broad-spectrum fungicide—was used to control all foliar fungal diseases, while copper hydroxide was used to control foliar bacterial diseases. The untreated plots were used to determine the effects of all the foliar diseases on the grain yield of common beans at Chitedze and Bembeke.

The chemicals were applied using the manufacturer's recommended rates, with a spraying regime of seven-day intervals throughout the growing season. As a result, eight applications of the chemicals were made in the growing season in order to maximise disease control. Disease scores were recorded at the late podding stage, which was 63 days after sowing at Chitedze and 79 days after sowing at Bembeke. The disease scores were recorded on the CIAT scale of 1 to 9 points (Van Schoonhoven and Pastor-Corrales, 1987).

The bean pods were picked at physiological maturity. The fresh pods were dried further in the sun for about 10 days until they were completely dry. They were then shelled by hand and the seed was weighed to determine the yield per genotype and per chemical treatment. The seed yield per hectare was determined from the weight of the samples at 14% moisture content.

All the disease scores and seed yield data were subjected to an analysis of variance (ANOVA) using the MSTAT computer programme.

Results and Discussion

The results are presented in tables 1 through 4, at the end of this paper.

Results from Chitedze

Angular leaf spot

There was a higher incidence of ALS on the common-bean genotypes at Chitedze in the 1998/99 crop growing season than in the 1999/2000 season. Significant differences were detected between genotypes, which indicated that some genotypes were resistant to ALS. Genotypes Maluwa and Mlama 127 were noted to be resistant to ALS in the 1998/99 season.

In 1999/2000, the incidence of ALS was negligible. Even on the susceptible checks (Sapelekedwa, Nasaka, and EST 10), the incidence was very low. Therefore the scores for 1999/2000 could not be used to identify resistant genotypes in this season.

Common bacterial blight

The incidence of CBB disease on common beans in the trial conducted at Chitedze in 1998/99 was very high (scores ranging from 7–9), irrespective of whether the plants were untreated or treated with chemicals. This indicated that all the genotypes were highly susceptible to CBB.

In 1999/2000, as in the previous season, CBB was the most serious disease of common beans at Chitedze, but it is encouraging that three genotypes appeared to be resistant. These were Maluwa, Sapatsika, and AFR 619. The rest of the genotypes had a lower incidence of CBB than the susceptible controls Sapelekedwa and Nasaka. The third susceptible check, EST 10, also had a lower incidence of CBB.

Grain yield

The yields of all the genotypes screened in 1998/99 at Chitedze were disastrously low, ranging from 168 kg/ha to 692 kg/ha, indicating that none of the genotypes was capable of producing high yields.

In the 1999/2000 growing season, only Maluwa and AFR 619 produced higher yields than the untreated plants. Generally, at Chitedze, chemical control of foliar fungal and bacterial diseases does not seem to be feasible for incorporation in the IDM strategies for common beans in Malawi. This is based on more than five years of trials at Chitedze, in which there has been no benefit from chemical treatments for foliar fungal and bacterial diseases on the promising new common-bean genotypes.

Results from Bembeke

Angular leaf spot

In the 1998/99 growing season, the incidence of ALS was generally high on the untreated plants (scores ranging from 3–8), except for Mlama 127, which had the lowest ALS disease incidence (score of 3), indicating resistance to the disease.

The incidence of ALS on the plants treated with chlorothalonil was low (scores ranging from 2–4), indicating that chlorothalonil effectively controlled ALS on the genotypes screened at Bembeke in 1998/99.

In the 1999/2000 growing season, the highest incidence of ALS was recorded on the untreated susceptible check EST 10 (score of 6). It is, however, atypical that the incidence of ALS on the other untreated susceptible checks Sapelekedwa and Nasaka was very low (scores of 3 and 2, respectively). The incidence of ALS on the rest of the genotypes was also low. Although significant differences were observed between both the common bean genotypes and the chemical treatments, the low incidence of ALS on the untreated susceptible checks can only indicate that ALS is unpredictable and not uniform.

Common bacterial blight

In the 1998/99 growing season, the incidence of the CBB on the untreated genotypes at Bembeke indicated a genotypic response that ranged from moderately resistant to susceptible (scores ranging from 6–8). The following genotypes produced results that indicated moderate resistance to CBB: Maluwa, Sapatsika, and LSA 191. These could be promising candidates for the development of IDM strategies for CBB in beans.

It is interesting to note that chlorothalonil, which is a broad-spectrum fungicide, tended to suppress the incidence of CBB on common beans (scores ranging from 4–8 on the chlorothalonil-treated plots versus 6–8 on untreated plants).

In the 1999/2000 growing season, the incidence of CBB was very high on the untreated susceptible genotypes (Sapelekedwa and Nasaka, with scores of 7 and 9, respectively). The rest of the genotypes showed moderate resistance to CBB (scores ranging from 4–6). It was only LSA 191 that was resistant to CBB at Bembeke in 1999/2000 (score of 3). It is very interesting that LSA 191 has been consistently observed over two growing seasons to be resistant to CBB infection. Therefore, LSA 191 should be seriously considered for use in IDM strategies for the control of CBB in Malawi and probably in the SADC region.

Grain yield

The grain yields obtained at Bembeke in 1998/99 were also disastrously low. Yields from the untreated genotypes ranged from 160 kg/ha for Sapelekedwa to 986 kg/ha for Mlama 127. For plants treated with chlorothalonil, the yields ranged from 378 kg.ha-1 for Sapelekedwa to 1215 kg/ha for Sapatsika. However, the yields for most genotypes were better at Bembeke in the 1998/99 growing season than at Chitedze. Considerable increases in yield were obtained when chemical treatments for ALS and CBB were applied to Sapelekedwa, Maluwa, Sapatsika, Rao 55, LSA 191, and EST 10. These results indicated that control of foliar fungal diseases such as ALS led to a higher increase in grain yield (almost 50%) than the control of foliar bacterial diseases such as CBB, which led to a yield increase of almost 40% in the 1998/99 growing season at Bembeke (table 2).

The grain yields obtained at Bembeke in the 1999/2000 growing season were generally higher than those obtained in the previous season. The best yields on the untreated genotypes were produced by Sapatsika, Rao 55, and AFR 619. The other common-bean genotypes that produced good yields were Maluwa, Mlama 127, and LSA 191. Most genotypes treated with chlorothalonil produced very high yields. At Bembeke in the 1999/2000 growing season, control of ALS led to a yield increase of almost 70%. This clearly indicates that controlling foliar fungal diseases such as ALS leads to the highest grain yields being obtained. The control of CBB led to high yields from only a few genotypes, and a yield increase of only about 10%. These results are similar to those obtained in the previous season when the control of foliar fungal diseases led to a higher grain yield increase than the control of foliar bacterial diseases.

However, these results may be due to the chlorothalonil fungicide being a better and more efficient tool for eradicating foliar fungal diseases than copper hydroxide was in controlling foliar bacterial diseases.

CONCLUSIONS

1. Control of foliar fungal diseases with an effective fungicide, such as chlorothalonil, is easier to achieve and also leads to higher yield increases in common-bean genotypes than the control of foliar bacterial diseases.
2. The common-bean genotype LSA 191 consistently showed moderately resistance to CBB at Bembeke. Therefore, this genotype can be exploited in the development of IDM strategies for the production of common beans and also in breeding programmes in Malawi.
3. The judicious use of fungicides, such as chlorothalonil, to control foliar fungal diseases could be an important option in the production of common beans in areas where such diseases are serious every season, as at Bembeke.
4. The common-bean genotypes released by the breeding programme in Malawi—including Maluwa (CAL 113) and Sapatsika (DRK 57)—are good varieties for production by the farming community.
5. More research needs to be devoted to the development of more genotypes that have resistance to CBB, which is now considered to be the most important disease of common beans in Malawi.

TAKE-HOME MESSAGES

The released common-bean varieties, Maluwa (CAL 113) and Sapatsika (DRK 57), are suitable for production by the farming community in Malawi.

The control of foliar fungal diseases such as ALS with an effective fungicide like chlorothalonil is an important option in production strategies for the common bean in those areas in Malawi where these diseases are serious every season, such as at Bembeke.

The foliar bacterial diseases such as CBB are the most important diseases of common beans because they are the most challenging to manage in Malawi.

Table 1. Grain Yield Losses Caused by Fungal (ALS) and Bacterial (CBB) Diseases on Eight Common-Bean Genoypes Using Chlorothalonil and Copper Hydroxide, Chitedze, 1998/1999 Cropping Season

	Disease Scores (from 1–9) at 74 Days after Sowing							
	Angular Leaf Spot				Common Bacterial Blight			
Genotype	**Untr**	**Chlor**	**CuH_2O_2**	**Mean**	**Untr**	**Chlor**	**CuH_2O_2**	**Mean**
Sapelekedwa	3	1	5	3	8	7	7	7
Nasaka	3	1	4	3	8	7	8	8
Maluwa (CAL 113)	1	1	1	1	7	8	8	8
Sapatsika (DRK 57)	4	1	4	3	8	7	8	7
Mlama 127	1	1	2	1	7	7	8	7
RAO 55	5	2	6	4	7	7	8	7
LSA 191	3	1	1	2	7	7	7	7
EST 10	6	4	7	5	9	8	8	8
Trial Means	3	2	3	3	7	7	8	7
S.E. (±) Chemicals				0.62				0.12
Genotypes				0.39				0.46
C x G				0.68				0.80
C.V. (%)				50.03				21.72
Significance								
Chemicals				NS				NS
Genotypes				**				NS
C x G				NS				NS

	Grain Yield (kg/ha)				% Increase	
Genotype	**Untr**	**Chlor**	**CuH_2O_2**	**Mean**	**Chlor**	**CuH_2O_2**
Sapelekedwa	213	293	168	224	38	-21
Nasaka	428	379	321	376	-1	-25
Maluwa (CAL 113)	421	405	338	388	-4	-20
Sapatsika (DRK 57)	401	440	383	408	10	-4
Mlama 127	222	295	266	261	33	20
RAO 55	692	686	616	665	-1	-11
LSA 191	465	378	320	388	-19	-31
EST 10	355	467	232	352	32	-35
Trial Means	400	418	331	383	5	-17
S.E. (±) Chemicals				51.73		
Genotypes				60.42		
C x G				104.65		
C.V. (%)				54.69		
Significance						
Chemicals				NS		
Genotypes				**		
C x G				NS		

Note: On the CIAT disease scale, 1–3 = resistance; 4–6 = moderate resistance; 7–9 = susceptible. Untr. = Untreated; Chlor. = Chlorothalonil; CuH_2O_2 = Copper Hydroxide.

* Significant at *p* = .05.
** Significant at *p* = .01.
NS = Not significant.

Table 2. Grain Yield Losses Caused by Fungal (ALS) and Bacterial (CBB) Diseases on Eight Common-Bean Genotypes Using Chlorothalonil and Copper Hydroxide, Bembeke, 1998/1999 Cropping Season

Common bean genotype	Disease Scores (from 1–9) 74 Days after Sowing							
	Angular Leaf Spot				Common Bacterial Blight			
	Untr	Chlor	CuH_2O_2	Mean	Untr	Chlor	CuH_2O_2	Mean
Sapelekedwa	6	3	6	5	7	7	8	7
Nasaka	7	3	6	5	8	8	7	7
Maluwa (CAL 113)	4	2	3	3	6	4	5	5
Sapatsika (DRK 57)	6	4	5	5	6	4	6	5
Mlama 127	3	3	3	3	8	5	8	7
RAO 55	7	3	6	5	7	6	7	7
LSA 191	5	3	5	4	6	6	7	6
EST 10	8	3	6	6	8	7	8	7
Trial Means	6	3	5	4	7	6	7	7
S.E. (±) Chemicals				0.38				0.21
Genotypes				0.32				0.35
C x G				0.55				0.60
C.V. (%)				25.09				18.31
Significance								
Chemicals				**				**
Genoypes				**				**
C x G				**				NS

Genotype	Grain Yield (kg/ha)				% Increase	
	Untr	Chlor	CuH_2O_2	Mean	Chlor	CuH_2O_2
Sapelekedwa	160	378	417	318	136	161
Nasaka	535	514	604	551	-4	13
Maluwa (CAL 113)	490	1,031	816	779	110	67
Sapatsika (DRK 57)	750	1,215	840	935	62	12
Mlama 127	986	979	990	985	-1	0
RAO 55	601	913	1,000	383	52	66
LSA 191	611	962	1,059	877	57	73
EST 10	434	830	618	627	91	42
Trial Means	571	853	793	739	49	39
S.E. (±) Chemicals				68.52		
Genotypes				92.07		
C x G				159.48		
C.V. (%)				43.17		
Significance						
Chemicals				*		
Genoypes				**		
C x G				NS		

Note: On the CIAT disease scale, 1–3 = resistance; 4–6 = moderate resistance; 7–9 = susceptible. Untr. = Untreated; Chlor. = Chlorothalonil; CuH_2O_2 = Copper Hydroxide.

* Significant at p = .05.
** Significant at p = .01.
NS = Not significant.

Table 3. Grain Yield Losses Caused by Fungal (ALS) and Bacterial (CBB) Diseases on Eight Common-Bean Genotypes Using Chlorothalonil and Copper Hydroxide, Chitedze, 1999/2000 Cropping Season

Genotype	Disease Scores (from 1–9) 74 Days after Sowing							
	Angular Leaf Spot				Common Bacterial Blight			
	Untr	Chlor	CuH_2O_2	Mean	Untr	Chlor	CuH_2O_2	Mean
Sapelekedwa	1	1	1	1	7	6	5	6
Nasaka	2	2	3	2	7	7	6	7
Maluwa (CAL 113)	2	2	1	1	3	3	2	3
Sapatsika (DRK 57)	2	1	2	1	3	3	2	3
Mlama 127	3	2	2	2	5	3	4	4
RAO 55	1	1	1	1	4	4	3	4
LSA 191	1	2	2	1	5	4	4	4
EST 10	3	3	3	3	4	4	3	4
AFR 619	1	1	1	1	3	3	3	3
Trial Means	2	2	2	2	5	4	4	4
S.E. (±) :								
Genotypes				0.31				0.45
Chemicals				0.09				0.14
Chemicals x Genotypes				0.28				0.41
C.V. (%)				35.17				20.36
Significance								
Genoypes				**				**
Chemicals				NS				**
Chemicals x Genotypes				NS				NS

Genotype	Grain Yield (kg/ha)				% Increase	
	Untr	Chlor	CuH_2O_2	Mean	Chlor	CuH_2O_2
Sapelekedwa	272	204	312	6	-25	15
Nasaka	634	599	416	7	-6	-34
Maluwa (CAL 113)	1,667	958	877	3	-43	-47
Sapatsika (DRK 57)	544	455	386	3	-16	-29
Mlama 127	374	315	324	4	-16	-13
RAO 55	716	668	508	4	-7	-29
LSA 191	800	819	729	4	2	-9
EST 10	191	517	164	4	171	-14
AFR 619	1,324	1,080	1,476	3	-18	11
Trial Means	725	624	577	4	-14	-20
S.E. (±) :						
Genotypes				146.69		
Chemicals				52.79		
Chemicals x Genotypes				158.37		
C.V. (%)				49.34		
Significance						
Genoypes				**		
Chemicals				NS		
Chemicals x Genotypes				NS		

Note: On the CIAT disease scale, 1–3 = resistance; 4–6 = moderate resistance; 7–9 = susceptible. Untr. = Untreated; Chlor. = Chlorothalonil; CuH_2O_2 = Copper Hydroxide.

* Significant at $p = .05$.
** Significant at $p = .01$.
NS = Not significant.

Table 4. Grain Yield Losses Caused by Fungal (ALS) and Bacterial (CBB) Diseases on Eight Common-Bean Genotypes Using Chlorothalonil and Copper Hydroxide, Bembeke, 1999/2000 Cropping Season

	Disease Scores (from 1–9) 74 Days after Sowing							
	Angular Leaf Spot				Common Bacterial Blight			
Genotype	**Untr**	**Chlor**	**CuH_2O_2**	**Mean**	**Untr**	**Chlor**	**CuH_2O_2**	**Mean**
Sapelekedwa	3	3	3	3	7	6	7	7
Nasaka	2	3	3	3	9	7	8	8
Maluwa (CAL 113)	2	1	2	2	4	4	5	4
Sapatsika (DRK 57)	4	2	4	4	4	3	3	3
Mlama 127	4	2	3	3	6	4	4	5
RAO 55	5	2	4	4	6	5	6	6
LSA 191	3	1	3	2	3	5	3	3
EST 10	6	4	5	5	6	5	7	6
AFR 619	4	2	4	3	5	3	5	5
Trial Means	4	2	3	3	5	5	5	5
S.E. (±) :								
Genotypes				0.50				0.38
Chemicals				0.17				0.13
Chemicals x Genotypes				0.51				0.39
C.V. (%)				33.93				15.48
Significance								
Genoypes				**				**
Chemicals				**				**
Chemicals x Genotypes				NS				**

	Grain Yield (kg/ha)				% Increase	
Genotype	**Untr**	**Chlor**	**CuH_2O_2**	**Mean**	**Chlor**	**CuH_2O_2**
Sapelekedwa	247	611	326	395	147	32
Nasaka	497	795	434	575	60	-13
Maluwa (CAL 113)	892	1,743	1,455	1,363	95	63
Sapatsika (DRK 57)	1,194	2,003	1,424	1,541	68	19
Mlama 127	802	823	688	771	3	-14
RAO 55	1,323	1,712	1,125	1,387	29	-15
LSA 191	764	1,378	795	979	80	4
EST 10	365	1,049	559	657	187	53
AFR 619	1,285	2,174	1,476	1,645	69	15
Trial Means	819	1,365	920	1,035	67	12
S.E. (±) :						
Genotypes				174.80		
Chemicals				41.59		
Chemicals x Genotypes				124.76		
C.V. (%)				24.11		
Significance						
Genoypes				**		
Chemicals				**		
Chemicals x Genotypes				*		

Note: On the CIAT disease scale, 1–3 = resistance; 4–6 = moderate resistance; 7–9 = susceptible. Untr. = Untreated; Chlor. = Chlorothalonil; CuH_2O_2 = Copper Hydroxide.

* Significant at $p = .05$.
** Significant at $p = .01$.
NS = Not significant.

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COLLETOTRICHUM LINDEMUTHIANUM ON BEANS IN ETHIOPIA: GEOGRAPHICAL DISTRIBUTION, IMPORTANCE, PATHOGENIC VARIATION, AND MANAGEMENT

Tesfaye Beshir

ABSTRACT

This study looked at the occurrence of bean anthracnose in Ethiopia and confirmed its importance as a limiting factor for the production of this important pulse crop. Bean anthracnose was found to increase from year to year in farmers' fields due to the monoculture of a susceptible variety (Mexican-142), with very similar effects in the Rift Valley, southern zone, and western zones of the country. There is a mean actual yield loss of 62.4% due to bean anthracnose. Host resistance was examined and, among the resistant entries, 23 were found to have wide resistance across all locations.

RÉSUMÉ

Cette étude a examiné l'incidence de l'anthracnose du haricot en Éthiopie et a confirmé son importance en tant que facteur limitatif de la production. Au cours des années, l'anthracnose du haricot a pris de plus en plus d'importance dans les champs des agriculteurs du fait de la monoculture d'une variété sensible (Mexican-142). Les mêmes effets ont été notés dans la Vallée du rift et les zones situées au sud et à l'ouest du pays. Les pertes de rendement dues à l'anthracnose du haricot atteignaient en moyenne des taux de 62,4 %. La résistance de l'hôte a été examinée et parmi les espèces résistantes, on en a découvert 23 qui présentaient une résistance élargie sur tous les sites.

INTRODUCTION

The common bean (*Phaseolus vulgaris* L) is an important food legume, providing an essential part of the daily diet in Ethiopia. It is grown as a subsistence crop under traditional farming systems, usually as an intercrop with cereals, coffee, or *enset*. Under Ethiopian conditions, beans are well adapted to altitude ranges between 1200 m and 2000 m, and to rain-fed conditions (Stewart and Dagnatchew Yirgu, 1967). Common beans are grown in most parts of Ethiopia, but production is concentrated mainly in the east (Harerghe highlands), south and southwest (Sidamo and Wolaita), the west (Keffa and Wollega), and the Rift Valley. This wide geographical range is associated with a wide range of cultivars and diseases (Bos, 1974; Habtu Assefa, 1987).

Around 1980, the area under common-bean production was about 100,000 ha (Ohlander, 1980). Estimates of the national average bean yields at that time were low, about 600 kg/ha to 800 kg/ha, which may be due to a combination of several yield constraints, among which diseases play a major role (Habtu Assefa and Dereje Gorfu, 1985). These older records gave little attention to geographic distribution and economic significance. Disease epidemiology under farmers' conditions is nearly unknown.

Of the diseases affecting bean yields, bean anthracnose (*Colletotrichum lindemuthianum* sac. and magn.) is widely distributed in the major bean-growing districts of Ethiopia. There are heavy yield losses due to anthracnose wherever susceptible bean cultivars are grown. Recently, the occurrence of the disease in Ethiopia has increased significantly (Habtu Assefa, 1987; Plant Protection Research Center, 1989). However, there is very little information on the epidemiology and management aspects of the disease. Thus, this report presents the results of a survey, loss assessment, race identification, and varietal evaluation for resistance against bean anthracnose in Ethiopia since 1992.

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MATERIALS AND METHODS

Survey, laboratory, greenhouse, and field experiments for the anthracnose regional sub-project were conducted in the Plant Protection Research Center at Ambo during 1992–1995.

Survey

Survey data can help to describe the geographic distribution of the disease, its epidemiology and relative importance (Habtu Assefa, 1987; Plant Protection Research Center, 1989). The survey was conducted in major bean-production regions of the central Rift Valley (Meki, Ziway, Nazareth) where the altitude ranges between 1500 m and 1700 m above sea level, with high temperatures and erratic rainfall. The areas of Awassa, Wolaita, and Areka from Southern Ethiopia and Bako, Wollega, and Jimma from Western Ethiopia were included in this survey.

Haricot bean fields were assessed at an interval of 15 km to 20 km on farmers' and state farm fields along the main road. Sample units were selected by making a specified number of equally spaced paces; the nearest plant to the right foot was taken as the sample unit. Per sample field, 50 sample units (plants) were taken for disease assessment at growth stages close to R7 and R8 (Van Schoonhoven and Pastor-Corrales, 1987). Infected samples were also collected for laboratory analysis.

Race identification

Bean anthracnose specimens were collected from Ambo, Nazerth, Meki, Ziway, Awassa, Arsi-Negele, Areka, Jimma, Bako, and Admi-Tulu, where anthracnose is severe. In most cases, diseased pods, leaves, petioles, stems, and seeds having typical symptoms of anthracnose were collected. Isolation and single-spore cultures were prepared and inoculated on 12 standard differentials (Van Schoonhoven and Pastor-Corrales, 1987) under greenhouse conditions. The reaction of the differentials was recorded using a scale from 1–9, and race classification was based on the binary system (Barrus, 1981; Buruchara, 1991).

Greenhouse test

Five seeds of each differential were sown in 15-cm-diameter pots with three replications and kept for 10–15 days in the greenhouse at a temperature between 21 and 30. Ten-day-old seedlings were inoculated by spraying with a two-week-old culture of *Colletotrichum lindemuthianum* at the concentration of 1.2×10^6 sp/ml (Barrus, 1981) and then kept in the humid chamber for seven days. Each plant was then evaluated for its reaction against anthracnose disease.

Yield loss

Field experiments were conducted using RCBD with six replications. A susceptible cultivar (Mexican 142) was used to determine yield loss. Plot size was 4 x 3.2 m with eight rows in which four central rows were harvested. There were six treatments in the experiment. Four were spray programmes at intervals of seven days; the fifth was seed-dressing, and the control as the sixth treatment. Benomyl 20% at the rate of 2 g/litre was sprayed in accordance with the treatment type. Seed dressing was made from benomyl 20% at the rate of 0.5% kg/100 g of bean seed. Diseases were recorded for each plot every two weeks starting from the first spray, using a scale from 1–9. In addition, for intensive disease evaluation, 16 plants were randomly selected and tagged in each plot.

Data collected include leaf severity at three, five, and nine leaflets, infected pods/plant, pod severity, dead tissue, leaf area, incidence, seeds/pod, seed yield, seed weight, and the presence of other diseases.

Host-plant resistance

The International Bean Anthracnose Trial Nursery was provided by CIAT, Colombia, to facilitate the potential sources of resistance for the region. The trial was conducted from 1992–1995, comprising 100 entries every year. A susceptible cultivar, Mexican 142, was sown between and around the replications in order to increase the inoculum level. Resistant (Red Wolaita), intermediate (Black Dessie), and susceptible (Mexican 142) varieties were sown as checks after every 10 test entries. The design used was an RCBD with two replications, with plot size of 2 m x 0.60 m. Although the nurseries were exposed to natural infection, in some cases they were also inoculated with mixed anthracnose isolates. Disease reaction was evaluated before flowering , after flowering, and at podding stages on a 1–9 scale(Van Schoonhoven and Pastor-Corrales, 1987).

RESULTS AND DISCUSSION

Survey

During 1992–1995, surveys were conducted in some of the lowland areas of the Rift Valley, southern zone, and lower and mid-altitude areas (1600 m to 2150 m) of the western region. The results revealed the occurrence of different diseases throughout the major bean-growing regions of the country, the most common of which were anthracnose (*C. lindemuthianum* [Sacc. and Magn.] Bri. and Cac.), bean rust (*Uromyces appendiculatus* [Pers.] Unger and *U. phaseoli* [Pers]), common bacterial blight (*Xanthamonas campestris* pv. phaseoli [Erw. Smith] Dowson), angular leaf spot (*Phaeoisariopsis griseola* [Sacc.] Ferraris), and floury leaf spot (*Mycovellosiella phaseoli* [Drummond]).

The mean severity of anthracnose was 55.8%; rust, 37%; and CBB, 33.9% across all surveyed zones of the country. Furthermore, the severity of anthracnose was higher in the western zone and the Rift Valley (table 1). In farmers' fields, disease severity was generally high and the overall mean was 54.1% out of the 50 plants observed.

Table 1. Mean Severity of Anthracnose in the Major Bean-Growing Regions of Ethiopia, 1992–99

Location	Altitude (meters)	Growth Stage	Severity (%)		
			Anthracnose	Rust	CBB
I. RIFT VALLEY					
Mojo	1910	Podding	51.0	43.0	31.0
Meki	1690	Podding	69.1	44.0	31.0
Ziway	1600	Podding	61.1	45.0	30.0
Adamitul	1690	Podding	48.2	49.0	34.0
Alemaya	2020	Podding	49.3	39.0	31.0
Mean	-	-	55.7	44.0	31.4
II. SOUTHERN ZONE					
Awassa	1740	Podding	45.0	30.0	45.0
Wolita sodo	2010	Podding	93.0	45.0	35.0
Arsi Negele	1930	Podding	35.1	33.0	38.0
Mean			57.7	36.0	39.3
III.WESTERN ZONE					
Bako	1650	Podding	57.9	34.0	30.0
Didesa	1600	Podding	45.9	31.0	30.0
Metu	1610	Podding	35.1	29.0	25.0
Jimma	2000	Podding	72.3	35.0	33.0
Ambo	2150	Podding	59.3	30.0	38.0
Mean			54.1	31.8	31.2

In all four years, a total of 108 isolates were collected, some of which were from experimental fields where many bean genotypes were grown, predominantly Mexican 142, which has recently shown a higher incidence of anthracnose. This might be due to susceptibility of Mexican 142, which is widely grown in Ethiopia, to the relative increase of a race that affects it, an increase of inoculum levels in the field due to infected debris, or sowing of infected seeds (which contributes to the build-up of anthracnose inoculum in the region). Thus the prevalence and severity of the disease have steadily increased in farmers’ fields and experimental sites.

Race identification

In 1992, race studies were initiated and isolates characterised from different bean-growing regions in the country: Bako, Ambo, Ziway, Awassa, Areka, Adami Tulu, Meki Jimma, and Alem Tena. Fifteen races of *C. lindemuthianum* were identified (table 2). Among the 15 races, race 128 and 511 occurred most frequently in every location and were designated as the dominant occurring races. Races like 1, 1023, 898, 525, 1009, 499, 718, 952, 585, 961, 1011, 712, and 296 were unique to a single location (table 3).

Table 2. Race Study on Bean Anthracnose Collected from Different Locations

Differentials		Ambo	Awassa	Meki	Bako	Areka	Ziway	Jima
Michelite	1	1	1	1	R	1	R	1
MDRK	2	R	R	2	2	2	R	R
Perry Marrow	4	R	R	4	R	R	R	4
Cornell 48242	8	8	R	8	8	R	R	8
WIDUSA	16	R	R	16	R	16	R	R
Kaboon	32	R	R	32	R	32	R	R
Mexico 222	64	64	64	64	R	64	R	R
PI 207262	128	R	128	128	128	128	128	R
TO	256	R	256	256	256	256	R	256
TU	512	512	512	R	512	512	R	R
AB 136	1024	R	R	R	R	R	R	R
G 2333	2048	R	R	R	R	R	R	R
Race Denomination		*585*	*961*	*511*	*906*	*1011*	*128*	*269*

Note: R = Resistant. Numbers indicate susceptibility.

Table 3. Races of *Colletotrichum lindemuthianum* Identified, Different Locations, 1992–95

Year	Types of races								
	Ambo	Awassa	Bako	Ziway	Areka	A. Tulu	Meki	A. Tena	Jimma
1992	525 1	1009	898 1023	128 511	499	718	511 128	952	—
1993	585	1009 961	906	128 511	1011	712	511 128	952	269
1994	525 585	1009 961	898 906	128 511	499 1011	718 712	511 128	952	269
1995	525 585 1	1009 961	898 906 1023	128 511	499 1011	718 712	511 128	952	2697

The racial pattern of *C. lindemuthianum* for the 1995/96 crop season did not show any shift in races; however, insignificant variations in distribution was observed, compared to the preceding year.

Yield loss

The yield-loss study was conducted on bean anthracnose over four years on experiment stations and on-farm trials. The severity of the disease on the control plot was high at different stages, compared to the protected crops.

In 1992, due to low anthracnose levels, there was no difference in yields from fungicide treatments, but the other years, the level of disease was high enough for the effect of the disease on yield to be measured. The mean actual yield loss was found to be 62.4%, and the mean actual seed weight loss was 43.8%.(table 4), (Zadoks and Schein, 1979).

The anthracnose developed very quickly in the on-farm trials, with an average severity of 76.6%. The mean loss in yield was 67.2% (table 5).

Host-plant resistance

New sources of resistance for bean anthracnose were identified from among the accessions from different geographic regions with desirable agronomic traits, such as growth habit, grain colour, and size: 59% of the

Table 4. Effect of Bean Anthracnose on Yield and Yield Components of Haricot Bean, Ambo, 1992–1995

Treatment	Severity (%)	Pods/Plant	Seeds/ pod	Seed weight		Yield	
				Grams	Actual loss (%)	ton/ha	Actual loss (%)
7 days	11.8 D	18.9 A	5.8 A	15.8 A	49.4	2.025 A	62.8
14 days	17.9 C	13.3 C	4.5 C	11.1 C	27.9	1.385 C	45.7
21 days	25.1 B	13.3 C	4.3 CD	10.4 D	23.1	1.252 D	39.8
28 days	27.4 B	13.6 C	4.2 D	9.8 E	18.4	1.188 D	36.7
Seed treat.	16.1 C	14.9 B	5.1 B	13.5 B	40.7	1.646 B	54.3
Control	83.5 A	8.7 D	3.5 E	8.0 F	—	0.756 E	—
Lsd 0.01	2.633	0.735	0.21	0.57		0.07	—
CV	9.03	5.64	4.98	5.31		5.14	—

Table 5. Yield Loss in Haricot Beans from Bean Anthracnose, on-Farm Trial, Meki, 1994–95

Crop Season	Treatment	Anthracnose Severity (%)					Yield		Seed wt.	
		V_4	R_5	R_6	R_7	R_8	Grams/ plot	Actual loss (%)	Grams	Actual loss (%)
1994	P	9.3	13.4	16.1	19.7	19.3	1508.9		157.1	
1995	NP	15.3	35.3	45.9	55.5	67.8	522.2	65.4	111.8	28.8
	P	10.2	17.2	19.5	21.1	15.1	1680.5		146.9	
	NP	25.0	35.0	47.9	65.1	85.4	522.5	68.9	94.4	35.7
MEAN	P	9.8	15.3	17.8	20.4	17.2	1594.7		152.0	
	NP	20.2	35.2	46.9	60.3	76.6	522.4	67.2	103.1	32.2

Note: P = Protected; NP = Not Protected.
V4 = 3rd trifoliate leaves; R5 = Pre-flowering; R6 = Flowering; R7 = Pod formation; R8 = Pod filling.

entries were resistant at Meki, 71% at Ambo, 80% at Awassa, and 57% at Areka. Fewer entries were classified as intermediate.

Weather conditions during the evaluation periods were favourable for the development of both the crop and the pathogen (except at Awassa). Entries like AB 136, G 2333, Ecuador-299, BAT-448, contanex, Negrow-150, Eth-39, Perry Marrow, ACV-17, Princor, CEN 60970, PVAD 1184, PVAD 791, PAD 37, A 4754, A 613, G 18549, G 19175, G 02618, G 05653, G 11680, VRB 81069, G 07199 were resistant across all locations. About 50 landraces have been collected to be tested against anthracnose on the basis of Meso-American and Andean pathogen gene pools.

CONCLUSIONS

Bean anthracnose, rust, CBB, ascochyta blight and angular leaf spot were the major diseases of the common-bean crop in the surveyed areas of the country.

The race analysis of bean anthracnose revealed 15 races to exist in Ethiopia, based on the differential variety test. Among these, race 128 and 511 were consistently found in all the test locations.

There was a yield loss of 62.8% due to anthracnose, justifying its economic importance in Ethiopia.

Nine varieties showed a high degree of resistance against bean anthracnose in all locations. These materials can be of great help in the bean-breeding programme of the East African and Great Lakes Region where similar races of the pathogen exist.

Recommendations

The materials that were resistant at all the tested sites were recommended to the national program. Some of these materials are already in the breeding program at Nazareth Research Center, Ethiopia.

FUTURE PLANS

1. monitoring races of bean anthracnose in Eastern Africa with collaborating countries (Kenya, Uganda, Madagascar, and Tanzania)
2. studying the virulence and aggressiveness of the bean anthracnose races obtained in the region
3. developing a race map for African bean anthracnose in Eastern Africa
4. continuing germplasm evaluation, including non I-gene PADN and IBCMBRN or breeding lines developed in specific programs

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Development of an Integrated Pest and Resource Management Package for the Control of Bean Stem Maggot (*Ophiomyia* spp.) in Malawi

E. H. Kapeya, R. M. Chirwa, and P. J. Z. Mviha

Abstract

*Fifteen IPM packages with a combination of five different options for the control of bean stem maggot (BSM) (*Ophiomyia *spp.) were tested at Chitedze, Ntchenachena, and Bembeke Agricultural Research Stations. These included fertiliser, seed dressing, earthing-up, foliar insecticide, and the use of resistant varieties. The performance of each package was evaluated based on several factors, such as plant mortality due to BSM, number of BSM on dead plants, damage scores, parasitoid populations, and seed yield. The results indicated that the use of both chemical and cultural practices, together with host-plant resistance, was superior over strategies that had one or more options missing. The advantage of chemical spraying over seed dressing is also discussed. Since the use of chemicals may not be feasible, they could be substituted with botanical pesticides, such as neem, *Tephrosia *spp., and other locally available botanicals. There is a need to explore the availability of such indigenous knowledge from bean growers in the major bean-growing areas of Malawi.*

Résumé

*Quinze ensembles de techniques agricoles de lutte intégrée contre les ravageurs associés à cinq différentes options de lutte contre la mouche du haricot (*Ophiomyia *spp.) ont été expérimentés aux stations de recherche agricoles de Chitedze, Ntchenachena et Bembeke. Ces ensembles comprenaient des fertilisants, la désinfection des semences, la pratique du buttage, des insecticides foliaires et l'utilisation de variétés résistantes. Les résultats de chaque ensemble ont été évalués sur la base de différents facteurs, tels que la mortalité par rapport au nombre de mouches, les taux de dommages, les populations parasitoïdes et le rendement des semences. Les résultats ont indiqué que l'utilisation de substances chimiques et de pratiques culturales associées à la résistance de la plante-hôte étaient préférables aux stratégies qui excluaient l'une ou plusieurs de ces options. L'avantage de la pulvérisation de substances chimiques par rapport à la désinfection des semences est également montré. Lorsque des substances chimiques ne peuvent pas être utilisées, elles peuvent être remplacées par des pesticides botaniques tels que le margousier, *Tephrosia *spp., et d'autres produits végétaux disponibles localement. Il est nécessaire d'étudier les connaissances indigènes des cultivateurs de haricots disponibles dans les principales régions de cultures du haricot du Malawi.*

Introduction and Literature Review

The common bean, *Phaseolus vulgaris*, is a good source of protein for the majority of people in both urban and rural communities in Malawi. Beans are also a source of cash and foreign-exchange earnings. However, bean productivity in Malawi, like that of most grain legumes is constrained by insect pests, among other factors (Anon., 1995). On-farm surveys have indicated insect pests like the bean fly (*0phiomyia* spp.), leaf beetle (*0otheca* spp.), and aphids (*Aphis fabae*), to be the main pests of beans in the country. While bean flies and leaf beetles are important during the main cropping season, aphids tend to be more serious on winter crops or in times of severe drought.

The survey reported here confirmed earlier findings that showed bean flies to be the main insect pest on beans in the country, (Kapeya et al., 1993; Letourneau, 1994). In Africa, bean flies have been reported to caused the total yield to be lost in some seasons (Karel, 1989). In Malawi, yield losses of up to 49% have been reported in the southern region, justifying the search for appropriate control measures (Kapeya et al., 1993). Various control methods for bean flies include applications of endosulfan, dimethoate, and imidacloprid as seed dressings or foliar sprays (Trutmann et al., 1992; Abate, 1991; Ross, 1997); cultural

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practices, such as earthing-up, increased plant density, time of planting, oil amendments, and soil moisture preservation through mulching (Ampofo, 1993; Letourneau, 1994; Ross, 1997). However, the efficiency of these practices depends on the time of application and environmental conditions, and in some communities, some of the methods may be incompatible with traditional practices (Ampofo, 1993). There are also sources of resistance that can be used to develop host-plant resistance as a control mechanism (Ross, 1997).

Since the efficiency of the cultural methods depends on time of application and environmental conditions, it is unlikely that a single practice can be recommended for consistent, long-term control of the bean fly. The use of an integrated approach would therefore be appropriate, since this would offset the failure of any single method. In addition, while not condoning the use of chemicals, we note that further control can be achieved if insecticide use is incorporated with cultural control methods. It is importance to improve the method of applying insecticides in order to decrease contamination of the broader agro-ecosystem to improve the survival of natural enemies. Seed treatments with systemic pesticides are one possible chemical option since they use minimal dosages and high ecological selectivity compared to sprays (Metcalf, 1980).

Furthermore, IPM approaches that are presented as packages should take farmers' socio-economic and environmental circumstances into consideration, bearing in mind the fact that most Malawian farmers rely on their own or family labour for both farming and earning off-farm income, which is, in most cases, in short supply. Similarly, these packages should be developed with the low income-earning capacity of smallholder farmers in mind. Finally, they should ensure reduced disruption of the ecosystem through proper selection of chemical insecticides.

It is therefore the general objective of this proposed work to develop an IPM package for use in different agro-ecological zones for the control of the bean fly (*0phiomyia* spp.) in Malawi. Specifically, the research will examine the impact of different IPM packages on the biological environment.

MATERIALS AND METHODS

The trial was carried out in three areas—Bembeke, Chitedze, and Ntchenachena—in a randomised complete block replicated three times. Gross plot was five rows, 4 m long and 50 cm apart with a net plot of 3 central rows of 3 m each. Beans were planted 15 cm apart on ridges. Infested rows of Nasaka were planted between treatment plots and replicates three weeks before bean planting. Treatments included 15 combinations of control strategies, such as fertiliser application (F), seed dressing (SD), earthing up (E), foliar insecticide spray (Fs), and use of resistant (R) or susceptible (S) varieties.

Two varieties, susceptible Nasaka and resistant EXI 52 were used. Dimethoate (20 EC) was used to control bean fly adults from one week after emergence to three weeks later. Earthing-up was done from two weeks after emergence when weeding was required. Imidacloprid was used for seed dressing at 5g/kg of seed, and fertiliser was applied at 300 kg/ha using 23:21:0+4S.

Data were collected on the plant stand at one week after emergence, total plant mortality and total bean flies emerging from the dead plants, number of parasitoids emerging from collected pupae, damage score of sampled plants, and pod and seed yield.

RESULTS AND DISCUSSION

Mortality due to bean stem maggots

Mortality was significantly different ($p > .001$) at all sites but was higher at Chitedze than Ntchenachena and Bembeke. In general treatments 13, 14, and 15 (which lacked both insecticide treatments and fertiliser applications) had the highest mortality from bean stem maggots (BSM) (table 1).

Number of bean stem maggots from dead plants

There were also higher BSM populations at Chitedze than at Ntchenachena, with significant differences ($p > .05$) at both locations. Again, treatments 13, 14 and 15 had the greatest infestation.

Damage score

Significant differences ($p >.001$) in damage scores were found at Ntchenachena but not at Chitedze, where the mean damage score was high (see table 1).

Table 1. Effect of IPM Packages on Bean Fly Infestation and Yield of Phaseolus Beans

Treatment	Mortality due to BSM	Total BSM	Number of Parasitoids	Damage score	Pod yield	Seed yield (kg/ha)
Chitedze, 2000						
Sd, F,E, R	1	0	0	1.0	783	375
Sd, F,E, S	1	3	0	1.0	770	355
Sd, F, R	2	0	0	1.0	387	217
Sd, F, S	2	4	0	1.0	606	285
Sd, E, R	4	8	7	2.0	470	160
Sd, E, S	2	5	3	1.0	265	135
Fs, F,E, R	1	4	0	1.0	1105	630
Fs, F,E S	1	5	0	2.0	1069	580
F,E R	1	4	2	1.0	386	165
F,E, S	3	8	0	3.0	447	160
F, R	1	2	11	1.0	440	250
F, S	2	6	0	3.2	404	180
E, R	9	16	0	4.5	116	100
E, S	17	36	4	5.0	100	30
No control	17	40	1	5.0	0	0
Mean	4.2	9.4	2	2.2	489.9	241.5
SE	0.3	0.8			185	91.3
Significance	***	***			***	***
Ntchenachena, 2000						
Sd,F,E, R	0	0	2	1.0	891	508
Sd, F,E., S	0	0	2	1.0	325	192
Sd, F, R	0	0	0	1.0	1016	533
Sd, F, S	0	0	0	1.0	258	150
Sd, E, R	1	0	3	2.0	240	317
Sd, E, S	0	0	2	1.0	267	176
Fs, F,E, R	0	4	2	3.0	147	583
Fs, F,E S	5	7	2	3.4	141	425
F,E R	0	0	1	1.0	200	175
F,E, S	12	14	16	3.6	1225	620
F, R	0	0	0	1.0	100	59
F, S	5	14	1	3.0	866	420
E, R	3	1	0	1.0	500	290
E, S	7	23	5	3.7	330	60
No control	9	27	7	4.5	250	60
Mean	2.8	6.0	3	2.1	322.9	304.5
SE	0.3	0.8			122	115
Significance	***	***			***	***

Table 1. (continued)

Treatment	Mortality due to BSM	Total BSM	Number of Parasitoids	Damage score	Pod yield	Seed yield (kg/ha)
Bembeke, 2000						
Sd, F,E, R	0	1	0	1.0	850	427
Sd, F,E, S	0	0	0	1.0	1165	566
Sd, F, R	0	0	0	1.0	716	627
Sd, F, S	0	0	0	1.0	564	376
Sd, E, R	2	6	1	3.4	459	306
Sd, E, S	0	0	1	1.0	929	666
Fs, F,E, R	2	4	1	3.0	810	540
Fs, F,E S	2	6	2	3.4	785	523
F, E, R	3	7	2	4.0	315	240
F,E, S	11	12	6	4.9	322	215
F, R	0	2	0	1.3	465	310
F, S	1	6	0	3.5	195.2	122
E, R	0	1	0	1.0	106.5	78.
E, S	17	23	10	4.4	73.8	40.6
No control	23	27	11	5.0	0.0	0.0
Mean	4.06	6.33	2	2.6	517.0	336.0
SE					195	127
Significance	***	***			***	***

*** *p* =.001.

Parasitoid population

Differences in parasitoid populations were significant (*p* >.05) among the different control strategies; however, insecticide control did not seem to reduce the population of parasitoids at Chitedze, where some control packages incorporating chemical control had high populations. This is in contrast to Ntchenachena, where only those strategies that did not include chemical control had high parasitoid populations.

Yields

Yield differences were significant (*p* >.001) at both sites, where high yields were observed when foliar spraying was combined with fertilisers, earthing-up, and the use of a resistant variety.

The results confirms the superiority of using both chemical and cultural practices together with host plant resistance over those control strategies that have one or more of these strategies lacking. In addition chemical control by spraying has shown to be more superior to seed dressing. While these results indicate the importance of integrating all four control strategies in controlling BSM, it is however not known whether this is economical or not. It is therefore imperative that an economic analysis be done to assess whether farmers are better off adopting a package that includes all control strategies.

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CONTRÔLE DE *AGROTIS IPSILON*, UN DES RAVAGEURS DU HARICOT À MADAGASCAR

Richard Randriamanantsoa

RÉSUMÉ

Pratiquée dans différentes régions de Madagascar, aussi bien en saison (dans les collines) qu'en contre-saison (sur rizière), la culture du haricot commun, Phaseolus vulgaris, *constitue une importante source de revenu pour les paysans malgaches. Cependant elle est sujette à des attaques par des ravageurs dont les principaux sont* Apoderus humeralis *et* Agrotis ipsilon. *Une étude réalisée avec la participation d'une communauté paysanne a évalué des méthodes visant à protéger les cultures de haricotpar la maîtrise du ravageur* Agrotis ipsilon. *Elle a permis de constater que le traitement des semences soit par l'application du fongicide/insecticide APRON+ 50 D, soit par l'épandage d'appâts empoisonnés composés de son de riz, sucre, diazinon et d'eau permet de réduire les dégâts occasionnés par ce ravageur. En outre, l'étude a révélé que la poudre de graines de* Melia azedarach *utilisée comme protection naturelle, inhibe la germination des graines de haricot tandis que la pratique paysanne qui consiste à épandre de la cendre avant le semis est efficace.*

ABSTRACT

In Madagascar bean crops are one of the farmers' main sources of income. The common bean, Phaseolus vulgaris, *is cultivated throughout the island's different regions and during various seasons (the rainy season on the hills and off-season cultivation on irrigated rice fields). However, the crops are threatened by insect pests, mainly* Apoderus humeralis *and* Agrotis ipsilon, *which attack the plants during the vegetative stage. A study was undertaken, with farmer-community participation, to assess the effects of various pest-control methods on* Agrotis ipsilon. *Findings showed that both the chemical seed treatment APRON+ 50DS (10% Metalaxyl + 34% Fioradicarb + 6% Carboxin) and the use poisoned baits made up of rice bran, sugar, Diazinon, and water were effective in reducing the damage caused by* Agrotis ipsilon. *Test results also revealed that the use of* Melia azedarach *powder, as a botanical pesticide, had an adverse effect on bean sprouting, while the local practice of spreading ash along planting rows before sowing is effective.*

INTRODUCTION

Madagascar est la plus grande île de l'océan Indien, avec une superficie de 592 000 km^2. Le riz est la principale culture et constitue l'aliment de base des Malgaches. Les cultures industrielles (canne à sucre, vanille, girofle, etc.) et les cultures maraîchères et vivrières (maïs, soja, manioc et haricot) constituent les principales sources de revenu des paysans.

Le haricot est cultivé partout dans l'île, aussi bien dans la zone côtière que sur les Hauts-Plateaux—culture de bas-fond et culture sur « tanety » (colline). Selon les régions, et en fonction de la pluviométrie et de la disponibilité des terrains, la culture se pratique une, deux ou trois fois par an : culture de saison, de demi-saison et de contre-saison (sur les rizières). Dans les régions des Hauts-Plateaux, le haricot est cultivé deux fois par an, par suite de l'exiguïté des parcelles, qui sont également destinées à d'autres cultures. Comme toutes les cultures, le haricot est sujet à de nombreuses attaques de ravageurs, dès le stade levée et jusqu'au stockage. *Apoderus humeralis, Ophiyomia* sp. et *Agrotis ipsilon* figurent parmi les principaux ravageurs menaçant le haricot durant son cycle végétatif. Le travail présenté ici s'insère dans la recherche de solutions pour aider les paysans à résoudre leurs problèmes, et plus particulièrement à s'armer contre les attaques d'*Agrotis ipsilon*, ravageur très connu des paysans qui menace leurs cultures de haricot, de tomates et de maïs.

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Matériels et Méthodes

Conduite

Ce travail a été conduit avec une communauté paysanne de la commune d'Ambohimiarivo, dans la sous-préfecture d'Antsirabe II. Situé à 35 km d'Antsirabe, ce site est l'une des principales zones productrices de la région, zone de cultures fruitières (raisin, pèche, pommes), maraîchères (principalement de la tomate) et vivrières, notamment le haricot. La variété de haricot *Soafianarana* est la plus courante mais depuis notre intervention dans la communauté beaucoup de paysans ont adopté les nouvelles variétés *Goiano précoce, Ikinimba*, *G13671* et *Xan 76.*

L'approche participative a été la démarche adoptée pour mieux impliquer les paysans.

Mise en place

Une discussion préliminaire avec les paysans a permis de connaître leurs pratiques de protection des cultures contre les attaques d'*Agrotis ipsilon*, de manière à pouvoir en tenir compte dans les différents traitements utilisés. Trois localités ont été considérées pour la conduite du travail.

Pour l'étude, la variété *Soafianarana* a été utilisée. Le semis a été réalisé en ligne, avec un écartement de 10 x 50 cm, à raison de 1 graine par poquet. Avant le semis, chaque parcelle élémentaire mesurant 12 m^2 (3 x 4 m) a été fertilisée d'une dose de 10 tonnes de fumier de ferme par hectare, en apportant 200 kg de NPK et 300 kg/ha de dolomie par hectare. Les paysans ont exécuté tous les travaux de préparation du sol et d'entretien (sarclage). La mise en place du dispositif a été précédée d'une séance de formation sur les différents stades du haricot, sur la biologie du ravageur, sur les différents traitements proposés et les conditions d'expérimentation requises.

Dispositif expérimental

Nous avons utilisé un dispositif en blocs à quatre répétitions et appliqué les six traitements suivants :

T_0 = témoin non traité

T_1 = pratique paysanne (utilisation de la cendre à raison d'un kilogramme par parcelle élémentaire)

T_2 = traitement des semences par un produit chimique, le fongicide/insecticide Apron plus 50 DS (métalaxyl 10 % + carboxine 6 %+ furathiocarbe 34 %). Doses de 250 g/100 kg de semences.

T_3 = traitement du sol par un produit chimique (basudine 10 G ; matière active diazinon). Doses de 15 kg/ha.

T_4 = utilisation d'appâts empoisonnés (son de riz + basudine 10 G + sucre + eau). Doses de 30 kg/ha.

T_5 = traitement de semences à l'aide de la poudre de graines de *Melia azedarach* (Miliacea), utilisée à la dose de 500 g/10 kg de semences

Préparation des produits et application :

- La cendre provient généralement de l'incinération de débris végétaux (mauvaises herbes feuilles et branches d'arbres que les paysans ramassent un peu partout) ; elle est appliquée le long de la ligne de plantation avant le semis.
- La poudre des graines de *Melia. azedarach* est obtenue en pilant des fruits mûrs de *M. azedarach* pour séparer la pulpe de la graine ; la graine est séchée, puis broyée et réduite en poudre ; la poudre est mélangée aux semences au moment du semis.
- L'appât empoisonné est composé de son de riz mélangé au produit chimique, avec ajout de sucre et d'eau ; l'épandage s'effectue en surface le long de la ligne de plantation, le soir après le semis.

Observations et récolte

Dix jours après le semis, on dénombre les plants levés dans chaque parcelle élémentaire. Ensuite, aux stades V2, V3 et V4 de la culture, on compte les plants attaqués en notant bien par rapport à quel traitement.

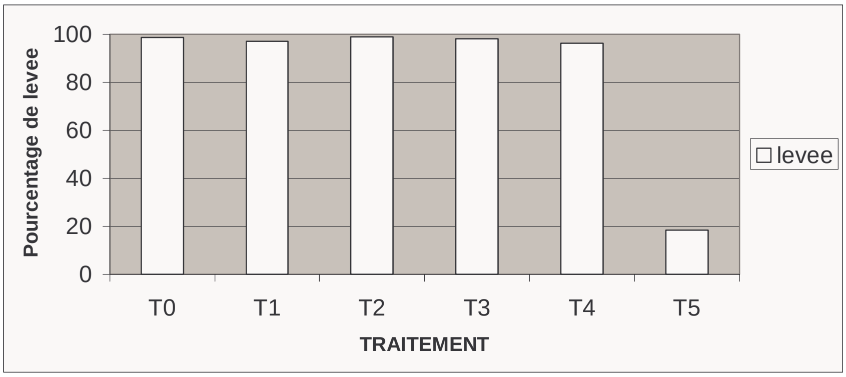
Chaque parcelle élémentaire fait l'objet d'une récolte séparée ; les produits recueillis sont pesés séparément.

RÉSULTATS ET DISCUSSION

Levée des plants :

La levée des plants a été satisfaisante dans toutes les parcelles, sauf dans celle où les semences ont été traitées avec la poudre de *Melia azedarach*. Le pourcentage de levée variait de 98,47 à 18,47 : le meilleur résultat fut obtenu avec le traitement T_2, à l'Apron +50 DS (figure 1). Le pourcentage le plus faible correspondait donc au traitement des graines avec de la poudre de *Melia azedarach* (T_5).

L'application de la poudre des graines de cette plante a affecté la germination des graines de haricot. En effet les graines traitées sont devenues molles et ratatinées, ce qui a entraîné la faible levée dans ces parcelles. Un test de germination effectué au laboratoire sur des semences enrobées de poudre de *Melia azedarach* a confirmé ce résultat.



T_0 = Témoin, T_1 = Pratique paysanne, T_2 = Traitement de semences par APRON +50DS, T_3 = Traitement de sol par Basudine 10G, T_4 = Utilisation d'appâts empoisonnés, T_5 = Traitement de semences par la poudre de *Melia azedarach*.

Figure 1. Pourcentage moyen de levée selon les différents traitements

Attaque selon les stades de la culture

La figure 2 fournit une représentation graphique de l'impact des différents traitements aux différents stades de la culture du haricot.

Stade V2
La faible levée observée avec le traitement des semences en les mélangeant à de la poudre de *Melia azedarach* a empêché l'évaluation des attaques de ravageur et l'analyse du rendement dans les parcelles concernées.

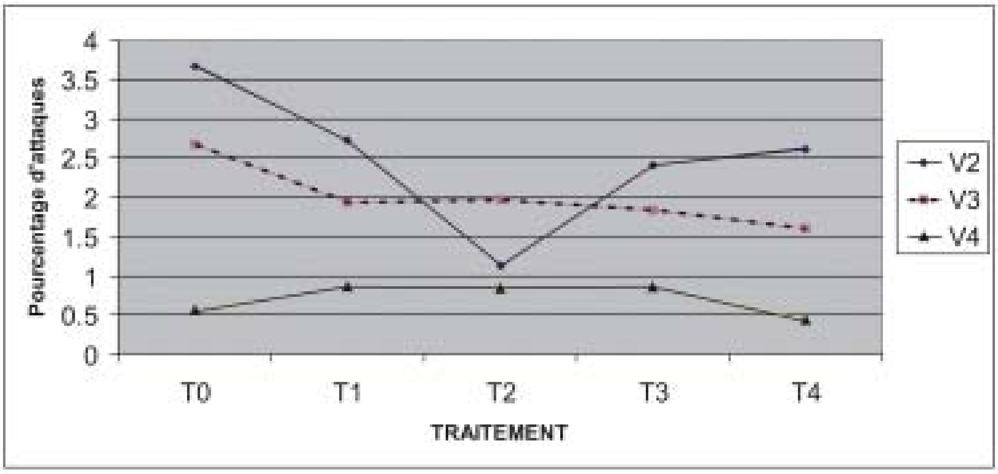
Dans les autres parcelles, malgré un taux d'attaque faible, variant de 3,89 % à 6,81 %, l'on a pu observer que les attaques subies au stade V2 de la culture étaient plus importantes qu'aux autres stades. Ceci montre que les dégâts d'*Agrotis ipsilon* sont plus à craindre pendant les premiers stades lorsque les plants sont jeunes.

On note que le traitement des semences avec APRON+ 50 DS (le mélange d'insecticide et de fongicide) donne le résultat le plus intéressant.

Stade V3
Au stade V3, on constate taux d'attaque faible pour tous les traitements, par rapport au témoin non protégé, y compris dans le traitement T_1 par la cendre. En effet l'utilisation de la cendre a protégé la culture contre les attaques des vers gris (*Agrotis ipsilon*), en ayant les mêmes effets que les autres traitements. Toutefois, une étude sur la nature des combustibles utilisés mérite d'être abordée.

Stade V4
Au stade V4 de la culture, le taux d'attaque ne dépasse pas 0,80 %. En effet, à ce stade les tiges se sont lignifiées et le ravageur ne réussit plus vraiment à les inciser. Les dégâts se limitent à la présence d'une incision au niveau de la tige. Il arrive que l'incision perce toute l'écorce et que la plante se fane et meurt mais une attaque d'*Agrotis ipsilon* n'est plus vraiment à craindre à ce stade.

La figure 2 montre à la fois qu'en général le taux d'attaque demeure relativement faible et que les attaques sont les plus nocives lorsque la culture est encore très jeune : la menace s'affaiblit dans les stades avancés de la croissance végétative. L'évolution des attaques sous l'influence des différents traitements indique l'intérêt



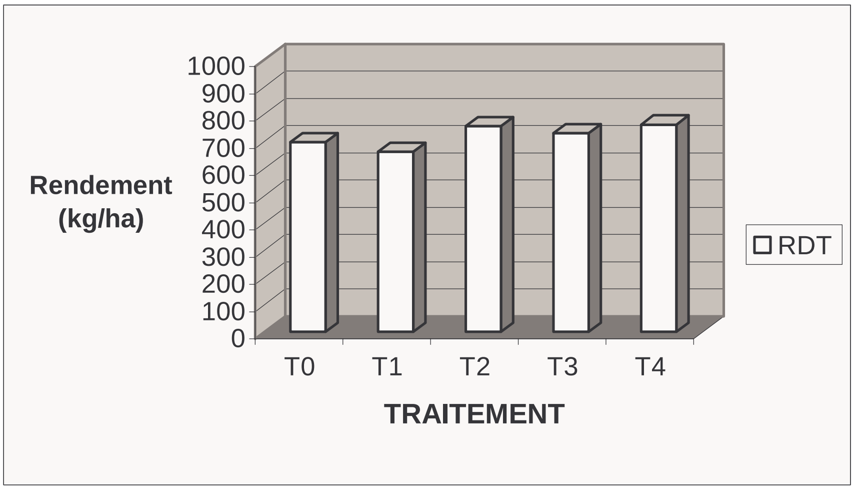
T_0 = Témoin, T_1 = Pratique paysanne, T_2 = Traitement de semences par APRON+50DS, T_3 = Traitement du sol par Basudine, T_4 = Utilisation d'appâts empoisonnés.

Figure 2. Pourcentages moyens d'attaque d'*Agrotis ipsilon* aux différents stades de la culture et en réponse aux différents traitements

de protéger le haricot contre les attaques d'*Agrotis ipsilon*. La protection chimique qui consiste à traiter les semences en appliquant un insecticide approprié (en l'occurrence, un mélange d'insecticide fongicide) est la plus intéressante.

Analyse du rendement

Malgré les divers traitements et malgré l'apport d'une bonne fertilisation, le rendement moyen du haricot n'a pas dépassé une tonne par hectare. Ceci n'est pas lié à l'attaque du ravageur mais plutôt à la variété elle-même. Cependant, une bonne protection permet d'améliorer le rendement (fig. 3) par rapport au témoin non protégé.



T_0 = Témoin, T_1 = Pratique paysanne, T_2 = Traitement de semences par APRON+50DS, T_3 = Traitement de sol par Basudine, T_4 = Utilisation d'appât empoisonné.

Figure 3. Rendement moyen (en kg/ha) selon les différents traitements

CONCLUSION

Les résultats des tests effectués dans le cadre de cette recherche ont permis de tirer les conclusions suivantes. On note d'abord que, contrairement à l'expérience acquise dans les cas du riz pluvial et du maïs, l'utilisation de la poudre des graines de *Melia azedarach* pour protéger les semences de haricot a une influence négative sur la germination des graines de haricot. Par contre, le traitement des semences en utilisant un produit chimique s'avère intéressant. Enfin, l'étude a confirmé l'importance de la pratique paysanne de mélanger de la cendre aux semences afin de protéger la culture de haricot contre les attaques des vers gris, *Agrotis ipsilon*.

Cette pratique paysanne est efficace : la cendre que beaucoup de paysans utilisent pour fertiliser leur culture par manque de fumier de parc réduit effectivement les dégâts causés par les attaques des ravageurs. Les paysans disposent de beaucoup de pratiques qui méritent d'être valorisées car elles sont simples et la plupart du temps disponibles sur place.

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FIELD MANAGEMENT OF *ACANTHOSCELIDES OBTECTUS* USING BOTANICALS, SYNTHETIC INSECTICIDES, AND ENTOMOPATHOGENS

J. A. Agona, M. S. Nahdy, and F. Owera-Odom

ABSTRACT

The common bean weevil, Acanthoscelides obtectus *(Say), is a primary pest that infests beans while still in the field and continues during storage. There is, however, a lack of information on the most susceptible stage of pod development, the relationship between bruchid damage and other pod pests, bruchid carry-over from the field into storage, and pest-management protocols. Studies were therefore conducted to establish the susceptibility of pods at different stages of development and the effect of chemical insecticides, bio-pesticides, and cropping systems on* A. obtectus *infestations. The onset of bruchid field infestations was determined with sticky-baited, sticky-non-baited, and water traps. The effect of insecticides and bio-pesticides on field infestations was determined by spraying beans under pre-determined regimens with different formulations of cow urine,* Phytolacca dodecandra, Tagetes minuta, Capsicum frutescens, Nicotiana tobacum, *suspensions of* Beauveria bassiana *spores, Ambush 5% EC, and Fenitrothion 50% EC. The influence of mixed inter-cropping, row inter-cropping, and sole cropping on field infestations was also investigated.* A. obtectus *was detected in the field as early as the pod-formation stage and its population increased significantly as the pods matured. The most susceptible pod stages were established as physiological and harvest maturity. Ambush, crude concoctions of tobacco,* Phytolacca *in water and soap, and* B. bassiana *fungal spores in water were quite effective in reducing* A. obtectus *infestations in the field. Beans harvested from the mixed inter-crop with maize were the least damaged.*

RÉSUMÉ

La bruche du haricot commun, Acanthoscelides obtectus, *est le principal ravageur qui s'attaque au haricot dans les champs et qui poursuit son action dans les lieux d'entreposage. Il existe toutefois un manque d'information sur la phase la plus sensible du développement de la gousse, sur la relation entre les dommages causés par les bruches et les autres ravageurs des gousses, sur le passage des bruches des champs aux lieux d'entreposage ainsi que sur les protocoles de lutte contre les ravageurs. Des études ont donc été réalisées afin de déterminer la sensibilité des gousses dans les différentes phases de développement et les effets des insecticides chimiques, des biopesticides et des systèmes de cultures sur les attaques de* A. obtectus. *Le commencement de l'attaque des champs par les bruches a été déterminé à l'aide de pièges englués munis d'appâts, de pièges englués sans appât et de pièges à eau. Les effets des insecticides et des biopesticides sur l'attaque des champs par les bruches ont été déterminés au moyen de pulvérisations des haricots selon des schémas prédéterminés comportant différentes formulations d'urine de vache,* Phytolacca dodecandra, Tagetes minuta, Capsicum frutescens, Nicotina tobacum, *de suspensions de spores de* Beauveria bassiana, *de perméthrine 5 % EC et de fenitrithion 50 % EC. L'impact des cultures associées, des cultures intercalaires et de la monoculture sur les attaques subies par les champs a également été étudié.* A. obtectus *a été détecté dans les champs dès la phase de formation de la gousse et sa population augmentait de manière significative à mesure que les gousses mûrissaient. La maturité physiologique et la maturité de récolte représentaient, pour les gousses, les phases les plus vulnérables. La perméthrine, des préparations crues à base de tabac,* Phytolacca *dans de l'eau savonneuse et des suspensions de spores fongiques de* B. bassiana *permettaient de réduire de manière efficace les attaques de* A. obtectus *en champ. Les haricots récoltés dans des champs de haricots et de maïs cultivés en culture intercalaire étaient les moins endommagés.*

INTRODUCTION

The common bean weevil, *Acanthoscelides obtectus* (Say), is widely distributed throughout sub-tropical and tropical regions and causes significant losses to beans in storage. Infestation often begins in the field and damage continues and intensifies during storage (Silim, 1990; Giga and Chinwada, 1992). Adult females

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oviposit in mature, dry pods (Huignard, 1979; Thiery and Jarry, 1985). Although it is generally known that infestation begins in the field, there is a lack of information on the most susceptible pod stage, relationship between bruchid damage and other pod pests, bruchid carry-over from the field into storage, and pest management strategies. Studies were therefore conducted at Kawanda Agricultural Research Institute (KARI) to establish the susceptibility of pods to *A. obtectus* at different stages of development and the effect of chemical insecticides, bio-pesticides, and cropping systems on *A. obtectus* field infestations. The study was conducted for two seasons.

OBJECTIVES

The objectives of the study were

- to determine the most susceptible stage of pod maturity to *A. obtectus* infestation and damage in the field
- to evaluate the efficacy of candidate botanicals, synthetic insecticides, and *Beauveria bassiana* on *A. obtectus* field infestations
- to determine the influence of inter-cropping beans with maize on *A. obtectus* field infestation
- to determine the level of bruchid carry-over from the field

MATERIALS AND METHODS

Experimental plots were established at KARI. Bean variety K20 was used exclusively and the recommended agronomic practices (i.e., planting density of 50 x 10 cm, weeding, blanket treatment of floral and foliage pests using synthetic insecticide) were observed.

Field population build-up of A. obtectus

To determine the onset of bruchid infestation in the field, sticky-baited, sticky non-baited, and water traps were used. The sticky traps measured 30 cm long, 15 cm wide, and 15 cm high and were deployed at a height of about 25 cm from the ground to correspond to the different pod development stages. Thirty whole bean seeds were placed on the sticky matrix of the trap as bait. The water traps were yellow disc plastic plates filled with 400 ml of water and raised 5 cm from the ground by use of wooden block. The traps, including water traps, were randomly placed in the bean field at 50% flowering. The bean plots measured 12 m x12 m and replicated four times. The trapped insects were examined, identified, and counted. Comparisons of the number of bruchids trapped after data transformation by $\sqrt{(x+1)}$ at the different pod development stages were made by two-way analysis of variance.

Determination of field infestation by A. obtectus

Pods were picked at different development stages, put in cloth bags to ensure no cross-contamination after harvest, and separately sun dried. The samples were divided into lots of five pods and incubated under ambient conditions until adult emergence.

Effect of bio-pesticides and synthetic insecticides on field infestations

The effect of insecticides and bio-pesticides on *A. obtectus* field infestations, was determined by spraying beans on pre-determined regimes with different formulations of pure ingredients or mixtures of cow urine, *Phytolacca dodecandra, Tagetes minuta, Capsicum frutescens, Nicotiana tobacum*, a suspension of *Beauveria bassiana* spores, Ambush, and Fenitrothion 50% EC, plus controls (untreated beans).

The treatments were prepared as follows:

- **Urine-based concoction,** formulated by mixing 1 kg each of pounded *P. dodecandra, T. minuta, C. fructescens*, ash, 5 litres of cow urine, and 250 ml of liquid soap; the mixture was then fermented for one week, filtered, and used
- **Water-based concoction,** formulated as above with water substituted for cow urine
- **Phytolacca extract** (fresh), formulated by mixing 1 kg of pounded *P. dodecandra* with 250 ml of liquid soap and 2 litres of water and filtered

- **Tagetes extract** (fresh), formulated by mixing 1 kg of pounded *T. minuta*, 250 ml of liquid soap, and 2 litres of water and filtered
- **Tobacco extract** (fresh), formulated by mixing 1 kg of pounded tobacco, 250 ml of liquid soap, 2 litres of water and filtered
- **Synthetic insecticides**, Ambush and Fenitrothion 50% EC, were used at 1 litre/ha
- ***Beauveria bassiana* fungal spores,** formulated with 2 kg of coarse maize bran containing fungal spores, 250 ml liquid soap, 4 litres of water and filtered

Prior to application, the botanical extracts were mixed with water in the ratio of 1:4. Spraying was initiated at the pod-filling stage and was continued at weekly intervals five times. The bean plots measured 2 m x 4 m. At maturity, each plot was harvested, beans were sorted into categories of pods damaged by sucking bugs and/or pod borers and undamaged pods. Each category was counted and the percentage damage calculated. The pods were then returned to the main sample, sun dried, threshed, and packaged according to treatment into 500-gm samples, which were incubated until adult emergence.

Effect of inter-cropping maize with beans on A. obtectus *field infestation*

We investigated the influence of mixed inter-cropping, row inter-cropping, and sole-cropping systems on field infestations of *A. obtectus* in beans. The bean plots measured 7.6 m x 2.4 m. In mixed inter-cropping, beans were planted along maize rows with a spacing of 10 cm between plants within rows. For row inter-cropping, two rows of maize were sown 75 cm apart and 30 cm intra-row. Two bean rows were then sown in between the consecutive maize rows with 40-cm inter-row spacing and 10-cm intra-row spacing. In sole cropping, plant spacing was maintained at 30 cm x 10 cm. At maturity, beans were harvested, sun dried, threshed, bulked into 500gm samples according treatment, and incubated until adult emergence.

RESULTS

A. obtectus was present in the field as early as pod formation, and the population increased significantly as the pods matured. The pod stages most susceptible to *A. obtectus* were physiological and harvest maturity (table 1).

Table 1. Mean Numbers of *A. obtectus* Trapped in Sticky-Baited Traps and Adult Emergence, by Pod Development Stage

Pod development stage	Means of *A. obtectus* (1st Season)	Means of *A. obtectus* (2nd Season)
Trapped in sticky-baited traps, by pod development stage		
50% Flowering	1.00 ± 0.00 (0)	1.00 ± 0.00 (0)
Pod formation	2.22 ± 0.09 (4)	2.44 ± 0.41 (5)
Pod filling	3.30 ± 1.08 (10)	2.82 ± 0.41 (7)
Physiological maturity	4.99 ± 0.09 (24)	3.60 ± 0.92 (12)
Harvest maturity	6.07 ± 0.18 (36)	5.06 ± 3.11 (25)
CV (%)	6.56	11.40
LSD (p = .05)	0.36	0.52
Adult emergence, by pod development stage		
Pod formation	1.00 ± 0.00 (0)	1.00 ± 0.00 (0)
Pod filling	1.00 ± 0.00 (0)	1.00 ± 0.00 (0)
Physiological maturity	1.74 ± 0.86 (2.25)	1.00 ± 0.00 (0)
Harvest maturity	2.64 ± 0.41 (6)	1.87 ± 0.08 (2.5)
CV (%)	18.54	7.13
LSD (p = .05)	0.47	0.128

Note: Means of data are transformed using $\sqrt{(x+1)}$. Actual means are shown in parentheses.

The sticky-baited trap was the most effective in detecting bruchid populations in the field.

Ambush was the most effective treatment in reducing bruchid infestation in the field, indicated by the low carry-over populations in storage. Crude concoctions of tobacco and phytolacca in water and soap as surfactants, as well as *B. bassiana* fungal spores in water were quite effective in reducing *A. obtectus* infestations in the field (table 2).

Table 2. Effect of Botanicals, Synthetic Insecticides, and *B. bassiana* on Field Infestation and on Damage by Pod-Sucking Bugs and/or Pod Borers

Treatment	Means of emergent *A. obtectus* (1st Season)	Means of emergent *A. obtectus* (2nd Season)
Control (untreated)	34.00 ± 2.28	41.25 ± 4.25
Phytolacca + Tagetes (water)	24.50 ± 2.24	27.25 ± 1.37
Phytolacca + Tagetes (urine)	14.00 ± 0.92	22.75 ± 2.14
Tagetes	22.00 ± 1.29	25.00 ± 0.96
Phytolacca	11.50 ± 1.71	14.25 ± 1.32
B. bassiana	10.50 ± 0.65	17.50 ± 1.04
Fenitrothion	9.50 ± 0.65	22.75 ± 2.14
Tobacco	6.25 ± 0.86	11.75 ± 0.86
Ambush	4.00 ± 0.96	4.75 ± 1.25
CV (%)	19.49	18.85
LSD (p = 0.05)	4.31	5.66
	Percent damage by pod borers 1st Season)	**Percent damage by pod borers (2nd Season)**
Control (untreated)	8.66 ± 0.22	6.53 ± 0.38
Phytolacca + Tagetes (water)	7.01 ± 0.02	5.06 ± 0.26
Phytolacca + Tagetes (urine)	6.17 ± 0.45	4.67 ± 0.06
Tagetes	6.64 ± 0.40	4.71 ± 0.34
Phytolacca	5.58 ± 0.21	3.35 ± 0.19
B. bassiana	6.12 ± 0.10	4.59 ± 0.07
Fenitrithion	4.89 ± 0.14	4.81 ± 0.18
Tobacco	5.47 ± 0.23	3.98 ± 0.07
Ambush	4.76 ± 0.19	3.24 ± 0.10
CV (%)	8.42	9.83
LSD (p = 0.05)	0.76	0.65

Note: Means of data are transformed using $\sqrt{(x+1)}$. Actual means are shown in parentheses.

There was a highly significant ($p < .05$) and positive relationship between adult emergence of *A. obtectus* and pod-sucking bugs and/or pod-borer damage (r = 0.926; 0.892; n = 30) during both seasons, suggesting that pod damage by borers and/or sucking bugs encourages field infestations (table 2)

There was a significant difference ($p < .05$) between the different cropping patterns in levels of bruchid infestation. Beans that were harvested from the mixed inter-crop with maize were the least damaged, compared to the row inter-cropped and sole-cropped beans (table 3).

Table 3. Effect of Cropping System on Emergence of adult *A. obtectus*

Cropping System	Means of emergent *A. obtectus* (1st Season)	Means of emergent *A. obtectus* (2nd Season)
Sole cropping	30.00 ± 2.49	24.50 ± 5.84
Row inter-cropping	10.25 ± 1.18	19.25 ± 4.35
Mixed inter-cropping	2.25 ± 2.49	2.50 ± 0.65
CV(%)	22.29	38.90
LSD (p = .05)	5.46	10.38

Note: Means of data are transformed using √(x+1). Actual means are shown in parentheses.

DISCUSSION

The presence of *A. obtectus* in the field was determined as early as the pod-formation stage, and its population increased with the subsequent development stages. The stage most susceptible to *A. obtectus* was at physiological and harvest maturity, possibly due to the presence of cracks and crevices on the pod where the weevil can oviposit, and the seeds are at the right stage to support development.

The results indicated that field application of chemical insecticides (Ambush and Fenitrothion 50% EC), tobacco, and phytolacca was very effective in reducing storage damage from *A. obtectus*. This confirms earlier findings by Huignard (1979) and Thiery and Jarry (1985) that *A. obtectus* infestations are mostly of field origin and can therefore be greatly reduced by field applications of insecticides. McIndoo (1945) noted that an extract of tobacco leaves can control insect pests on crops. The major active biological ingredient in tobacco is nicotine.

Mixed inter-cropping of beans with maize reduces field-to-storage transfer of *A. obtectus*. It is possible that maize, which is a non-host crop for the pest, may physically interfere with the ability of the pest to find its host. The success inter-cropping could also be attributed to pest evasion, from either visual or tactile cues, or the effect of shading. It could also be due to the reduced number of host plants in the mixture.

RECOMMENDATIONS AND CONCLUSION

It is recommended that the promising methods achieved on-station be evaluated under farmer-managed field conditions.

It is suggested that small-scale, subsistence farmers emphasise botanicals other than synthetic insecticides, which are difficult to procure, apply, and protect oneself against.

In conclusion, more investigation is needed for the mechanism and mode of action of the bio-rationals and the effects of cultural practices in combination with bio-rational applications for *A. obtectus* field infestations.

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L'UTILISATION DES POUDRAGES DE PLANTES MÉDICINALES DANS LA LUTTE CONTRE LES BRUCHES DU HARICOT AU KIVU

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RÉSUMÉ

Au Kivu, en République Démocratique du Congo, les bruches du haricot sont les ravageurs les plus nuisibles aux graines de haricot stockées. Les méthodes efficaces en usage impliquent l'utilisation des insecticides. Cependant plusieurs insecticides sont actuellement prohibés et ne sont pas accessibles aux petits fermiers du Kivu. D'où la recherche de solutions alternatives. Des plantes médicinales à propriétés insecticides ont été testées au laboratoire, en 2001 à Lwiro, afin de déterminer leur efficacité dans la lutte contre les bruches du haricot. Il s'est avéré que le mélange des poudres de plantes appliqué par les paysans du Kivu à la dose 200 g/kg de haricots est plus efficace encore que l'utilisation de la poudre d'une plante seule. Or la dose de 30 g de poudre de Maesa lanceolata *suit de près cette dose dite « paysanne » : elle aussi permet de réduire considérablement la prolifération des insectes et, par conséquent, les pertes de poids des stocks, qui deviennent négligeables.*

Mots–clés : Bruches du haricot ; lutte biologique contre les ravageurs/protection phytosanitaire ; poudrage de plantes médicinales insecticides ; Kivu, RD Congo

ABSTRACT

In the Kivu provinces in the east of the Democratic Republic of Congo, bruchid beetles form the most important post-harvest threat to beans. Methods for controlling bean weevils generally involve insecticides, some of which, however, are currently prohibited or inaccessible to the region's smallholder farmers. In 2001, as part of their search for alternative solutions, scientists at the Lwiro Research Centre carried out laboratory tests using a number of local medicinal plants with insect-repellent qualities to assess their effectiveness as a pest-control tool. A mix of plant powders used by local farmers (200 g/ kg beans) proved to be more effective than applying the powder of a single plant. However the 30 g/kg dose of Maesa Lanceolata *plant powder comes a close second to the 'farmers' dosage': it greatly reduces the emergence of bruchids, and any loss of stored bean stocks becomes insignificant.*

Keywords: Bruchid beetles (bean weevils); integrated pest management; medicinal, insect-repellent plant powders; Kivu, DR Congo

INTRODUCTION

En Afrique centrale, australe et orientale, le haricot commun (*Phaseolus vulgaris L.*), principale légumineuse cultivée pour ses graines, est consommée par 80 % des communautés humaines. Denrée peu onéreuse, le haricot couvre plus de 11 % des besoins en énergie alimentaire quotidiens des populations tant rurales qu'urbaines, et 22 % des besoins en protéines. Il joue donc un rôle important dans l'économie ménagère, dans la formation du capital paysan et dans la sécurité alimentaire des populations: plus de 11 % du revenu annuel paysan provient de la vente du haricot (David et al., 2000).

Les agriculteurs de la région du Kivu en République Démocratique du Congo cultivent plusieurs variétés et types de haricot à des fins commerciales. Comme les prix sur les marchés sont bas durant les périodes de récolte (février-mars et mai-juin), les paysans emmagasinent leurs récoltes en attendant une hausse des cours. Ce stockage dure généralement de trois à cinq mois, période pendant laquelle le haricot stocké est souvent attaqué par des ravageurs, dont les plus importants sont les bruches (*Acanthoscelides obtectus* et *Zabrotes*

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subfasciatus) (Masolwa et Nchimbi, 1991). Ces bruches perforent les graines conservées et abîment ainsi leur qualité commerciale (Appert, 1985; Autrique et al., 1987,1988; Allen et al., 1996; Ampofo et al., 1992; Ampofo, 1993, 1997; Cardona et al., 1992; Nahdy et Agona, 1993; Nahdy, 1994). En Afrique tropicale, les pertes causées par ces ravageurs sont estimées à 30–80 % (Delobel et Tran, 1993; Dent, 1991; Saxena, 1987).

Les scientifiques ont déjà développé et vulgarisé toute une gamme de méthodes et de techniques de lutte contre les bruches du haricot. Citons parmi celles-ci les insecticides de synthèse, l'hygiène des entrepôts, un séchage adéquat des graines avant le stockage, l'application de substances végétales (jus et huiles tels les huiles de neem, de ricin, de soja et de palme, le jus de banane, etc.), l'utilisation de substances minérales (latérites, sables, chaux, roches, cendres de bois, etc.) et enfin, le recours à des variétés résistantes aux coléoptères ennemis des stocks (Nahdy et Agona, 1993 ; Giga et Chinwade,1993; Sindibona et Kayitare, 1987; Kumar, 1991; Stoll, 1988; Gwinner et al.,1991; Ross, 1998). Or, en milieu rural, ces technologies bien développées et validées posent souvent un problème d'adoption et d'acceptabilité. Ainsi les insecticides de synthèse, bien qu'efficaces, ne sont pas disponibles ou bien coûtent trop cher. Certains d'entre eux sont de plus en plus prohibés : l'usage en est polluant, ils sont toxiques et donc nuisibles aux organismes et leurs environnements.

L'utilisation d'huiles végétales qui consiste à enrober les graines d'huile d'arachide ou de palme à raison de 5 ml/kg, s'est avérée très efficace contre les bruches. L'adoption de cette technologie en milieu paysan bute à un obstacle du fait qu'elle ne convient pas lorsqu'il s'agit d'emmagasiner de grandes quantités de denrées dans l'attente d'un prix rémunérateur sur le marché. Autre problème, les graines conservées de cette manière ont une faculté germinative très basse et nécessitent un temps de cuisson bien long. Les graines enrobées d'huile de palme deviennent souvent difficiles à vendre : elles rancissent et deviennent désagréables à consommer et, au marché, leur aspect extérieur détérioré déplait à l'acheteur.

Il importe donc d'utiliser des technologies de lutte contre les bruches qui veillent à ce toutes les qualités du haricot soient préservées pendant la conservation. Les paysans du Kivu estiment que certaines plantes médicinales constituent une bonne solution. Nous avons procédé à dresser l'inventaire de ces plantes insecticides et insectifuges qu'utilisent les paysans, pour ensuite évaluer leur efficacité : notre but était de voir si leur qualités justifient la diffusion de technologies basées sur leur utilisation, à toute la communauté paysanne intéressée par le stockage du haricot à des fins de commercialisation.

Le présent article résume les résultats préliminaires d'une étude portant sur le potentiel de protection de poudrages de certaines plantes présumées insecticides. Après avoir préparé des poudres de ces plantes, les chercheurs les incorporées, à différentes doses, dans les semences stockées qui ont d'abord connu une infestation artificielle de ravageurs de stocks.

MATÉRIELS ET MÉTHODES

Planification des essais

L'expérience a été réalisée sous la forme de deux principaux essais menés au laboratoire d'entomologie agricole du Centre de Recherche en Sciences Naturelles de Lwiro dans la province du Sud-Kivu. Le premier essai s'est déroulé du 5 mai au 5 novembre 2000 et le deuxième du 5 janvier au 4 juin 2001. Le centre de Lwiro se situe sur les rives ouest du Lac Kivu, à 1 650 m d'altitude et à 40 km de la ville de Bukavu en territoire de Kabare. L'on y trouve un climat de type Aw3, climat tropical humide tempéré par l'altitude et caractérisé par deux saisons : une saison pluvieuse de neuf mois (septembre–mai) et une courte saison sèche (juin–août). Le régime pluviométrique est bimodal, la première période allant de septembre à novembre et la deuxième de mars à mai (Munyuli, 2001). La moyenne annuelle des pluies est de 1 600 mm, celle de la température est de 19^0C, et l'humidité relative est en moyenne de 76 %. La région de Lwiro présente un relief montagneux, par endroits vallonné. Le sol est un ferrisol argilo-sableux, dérivant de roches sédimentaires, métamorphiques, cendrées volcaniques et d'alluvions récentes. On y cultive plusieurs cultures tropicales (haricot, manioc, et autres) et tempérées (blé, pomme de terre, etc.).

Le matériel utilisé

Les variétés

Pour le premier essai, nous avons testé les variétés haricot soja (G2828) et Kirundo (M'mpuyege en langue vernaculaire). Pour le deuxième essai, nous avons utilisé la variété M'Mafutala et la variété VCB 81012.

Ces variétés sont parmi les plus cultivées et les plus vendues sur les marchés locaux. Les variétés Kirundo, VCB81012 et G2828 seraient plus sensibles aux attaques des bruches que la variété M'Mafutala. Les paysans cultivent les variétés G2828 et M'Mafutala pour assurer leur subsistance, alors que les variétés Kirundo et VCB 81012 sont davantage destinées au marché.

Les échantillons utilisés nous ont été fournis par Mr. Musakamba, à la station de l'INERA-Mulungu. Fraîchement récoltés, les échantillons n'avaient subi aucun traitement insecticide. Avant d'être utilisées, les graines ont d'abord été gardées au réfrigérateur (4°C) pendant 15 jours pour anéantir les infestations latentes.

Les plantes
Les paysans du Kivu se servent de 50 espèces végétales pour protéger leurs cultures. Parmi toutes celles-ci, nous avons choisi les plantes les plus communément acceptées par tous les paysans comme de puissants insecticides naturels, et en tout premier lieu les espèces *Tagetes minuta* (Asteraceae), *Agava americana* (Agavaceae), et *Maesa lanceolata* (Myrsinaceae).

Les insectes utilisés
Les insectes utilisés sont de souche locale, issus d'un élevage au laboratoire à partir de populations mères récoltées dans les stocks en milieu rural. *Acanthoscelides obtectus* a été élevé sur le haricot suivant la méthode proposée par Valerie Wright et al. (in Sindibona et Kayitare, 1987). Les insectes ont été préalablement sexés, à l'aide d'un au microscope binoculaire, selon la méthode de Perris (cité in Kumar, 1991 et Sindibona et Kayitare, 1987).

Matériel et conditions de stockage
Nous avons conservé les graines dans des sachets désinfectés, qui ont ensuite été enfremés dans des boîtes en plastique (20 x 20 x 8 cm) couvertes d'un tissu en nylon et d'un couvercle perforé. Ces boîtes ont été placées dans un local du laboratoire même et gardées à une humidité relative moyenne de 76 % et une température moyenne de 22,5°C.

Planification de l'expérience et dispositif expérimental

Formulation des doses testées
En général, l'unité expérimentale était le sachet contenant 1 kg de graines placé dans la boîte en plastique décrite plus haut.

La récolte des plantes s'est faite à la machette, dans la région de Lwiro : toutes les parties coupées (écorces, feuilles, tiges, etc.) ont été séchées à l'air libre dans le séchoir de l'insectarium de la section d'entomologie du CRSN-Lwiro.

Après un séchage qui a duré quatre semaines, les plantes ont été pilées pour obtenir des farines granuleuses que l'on a ajoutées au contenu des sachets, en doses croissantes—0 g (témoin), 10 g, 20 g, 30 g de poudre de chacune des plante, et cela donc par unité de 1 kg de graines conservées. Une balance de précision a permis de relever les différentes pesées à 100 g près.

Aux traitements énumérés ci-dessus, nous avons associé une autre dose, dite la « dose paysanne ». En effet, lors des nos enquêtes menées en milieu paysan, nous avions découvert que des « brigades de recherche paysanne » s'occupaient à tester l'application d'une dose de 200 g de poudre de plantes mélangées pour 1 kg de haricots qui, nous assuraient ces paysans-chercheurs, était efficace contre les bruches. La dose en question contient un mélange de poudres de toute une gamme des plantes (de 14 à 20 plantes). Voici les noms des principales plantes utilisées :

1. *Tagetes minuta* (Asteraceae)
2. *Agava americana* et *Agava sisalana* (Agavaceae)
3. *Artemisia annuata* (Asteraceae)
4. *Maesa lanceolata* (Myrsinaceae)
5. *Tithonia diversifolia* (Asteraceae)
6. *Capsicum frutensis* (Piperaceae)
7. *Chenopodium ugandae*
8. *Mentha aquatica* (Lamiaceae)
9. *Vernonia amygdalina* (Asteraceae)
10. *Tetradenia riparia*
11. *Tephrosia vogelii*
12. *Phytolacca dodecandra* (Phytolacacaea)
13. *Eucalyptus* spp.
14. *Cupressus* spp.
15. *Piper guineense* (Piperaceae)
16. *Nicotiana tabacum* (Solanaceae)
17. *Ipomoea involucrata* (Convulvulceae)
18. *Pentas longiflora* (Rubiacea)
19. *Palisota schweinfurthii* (Commelinaceae)
20. *Darura stramonium* (Solanaceae)
21. *Haummaniastrum galeopsifolium* L. (Lamiaceae)

Dispositif expérimental

Comme nous l'avons indiqué pour le stockage, nous avons placé des sachets stérilisés remplis de graines de haricot dans des boîtes en plastique achetées au marché local, puis lavées et stérilisées (à la chaleur sèche). Les boîtes ainsi placées au laboratoire contenaient chacune 1 kg de haricot, un sachet pour chaque variété. Le poudrage des graines eut lieu une semaine après leur placement dans les sachets et chaque unité fut artificiellement infestée par un nombre donné de couples d'imagos. Le lâcher des insectes (imagos âgés de 4 jours) est intervenu 3 semaines plus tard, à raison de 10 couples sexés (premier essai) et 5 couples sexés (deuxième essai). Le dispositif expérimental monté au laboratoire était un dispositif en blocs casualisés. Le nombre de boîtes était de sept pour chaque traitement et chaque traitement a été répété sept fois. Le remuage des produits stockés n'a pas été jugé nécessaire.

Paramètres mesurés

Après sept mois de conservation dans ces conditions, nous avions procédé au dépouillement de données, en prélevant, pour chaque unité expérimentale (boîte), les paramètres suivants:

Le nombre d'insectes vivants ayant émergé (**N**)

Le nombre des graines trouées ou attaquées (**Na**)

Le nombre des graines saines (**Ns**)

Le poids des graines trouées (**Pa**)

Le poids des graines saines (**Ps**)

Traitement des données

Un comptage à vue des insectes présents dans les sachets a permis d'aboutir à un nombre moyen d'insectes vivants ayant émergé après la période de stockage.

À l'aide de la formule proposée par Golob (Sindibona et Kayitare, 1987, Kumar, 1991, Dent, 1991), l'on a calculé le pourcentage de perte de poids (P%) :

$$P\ (\%) = \frac{(Na \times Ps) - (Ns \times Pa)}{Ps\ (Na+Ns)}$$

Les résultats obtenus, à savoir les nombres moyens d'insectes vivants et le pourcentage moyen de pertes de poids, ont fait l'objet d'une analyse statistique(en utilisant le programme Genstat computer package).

RÉSULTATS ET DISCUSSION

Les deux tableaux placés plus bas présentent les résultats obtenus aux deux essais menés pour étudier l'effet de l'enrobage des graines de haricot par les poudres des plantes médicinales, sur le pourcentage de perte de poids et le nombre des imagos émergés de la bruche *Acanthoscelides obtectus*. Les moyennes ont été calculées à partir des données brutes recueillies pour les sept répétitions. Une analyse statistique de ces résultats a été effectuée en appliquant la méthode d'analyse de la variance complète après une transformation des données. Pour chaque plante testée, les calculs statistiques décèlent une différence significative (P = 0,005) entre les traitements (doses) considérées.

Le premier essai (tableau 1) fut mené du 5 mai au 5 décembre 2000. Le nombre de couples d'imagos lâchés au départ dans chaque unité expérimentale fut de 10.

Au bout de sept mois de stockage, on nota que le nombre d'insectes vivants ayant émergé était considérablement plus élevé dans les sachets témoins que dans les autres traitements. Le tableau 1 montre en effet que par rapport aux témoins (M0, A0 et T0), ce sont surtout les doses M2 et M3 de poudre de *Maesa lanceolata* (20–30 g par kilogramme de graines de haricot) et la dose paysanne de poudre mélangée (200 g/kg de haricot) qui ont fortement réduit le développement des insectes : sept mois après l'infestation originale par les 10 couples par unité expérimentale, le nombre moyen d'imagos est de 2,65 pour les traitements M3 (30g.) et de zéro suite à l'application du Mélange (200g), alors que, pour le témoin, la moyenne correspondante M0 est de 194,5 (tableau 1). Les farines granuleuses de *Maesa lanceolata* et le mélange de la dose paysanne ont eu le plus grand effet et réussissent le mieux à conserver les graines contre les bruches. Il convient de noter que cette réduction du nombre d'imagos émergés varie clairement d'une variété de haricot à une autre et que la réduction la plus sensible (1,9) a été obtenue avec la variété G2828, le haricot soja.

Pareillement, le tableau 1 montre que le pourcentage de perte de poids est considérablement plus important dans le cas des sachets témoins que pour ceux des autres traitements. En ralentissant fortement la

Tableau 1. Effet du poudrage des graines de haricot sur le ravageur *Acanthoscelides obtectus* : résultats du premier essai (7 mois ; 10 couples d'imagos)

			Variété + poids initial des graines					
			G2828 h.soja : 1kg n=2000 graines		Kirundo : 1 kg n=1366 graines		Moyenne générale	
Plantes	**Dose (g)**	**Traitement**	**P(%)**	**N**	**P(%)**	**N**	**P(%)**	**N**
Tagetes minuta	0	T0	81,00	234,00	96,00	306,00	88,50	270,00
	10	T1	77,00	151,00	83,00	170,00	80,00	161,50
	20	T2	51,00	87,00	66,00	110,00	58,50	95,00
	30	T3	30,00	65,00	28,00	66,00	29,00	65,50
Agava americana	0	A0	94,00	190,00	89,00	316,00	91,50	250,00
	10	A1	59,00	79,00	46,00	88,00	52,50	83,50
	20	A2	10,60	21,00	14,00	26,00	12,30	23,50
	30	A3	4,70	10,60	7,10	19,50	5,80	15,05
Maesa lanceolata	0	M0	91,00	174,00	92,00	215,00	91,50	194,50
	10	M1	21,00	45,00	19,00	66,00	20,00	55,50
	20	M2	1,70	6,50	1,90	4,50	3,60	5,50
	30	M3	0,40	1,90	1,16	3,40	0,75	2,65
Mélange	200	MDP	0,03	0	0.05	0	0,04	0
SED			0,07	0,94	0,02	2,67		

Légende:

P(%) : pourcentage de perte de rendement
N : nombre moyen des imagos émergés après 4 mois de stockage
n : nombre initiale des graines
Mélange : « dose paysanne » composée des poudre de plusieurs plantes (utilisée au Kivu)
SED: Erreur standard d'une différence entre les moyennes des traitements

prolifération des bruches, l'apport de la poudre de *Maesa lanceolata* (dose M3 surtout) et du Mélange(dose paysanne) a entraîné une perte de poids bien moins importante du haricot stocké : le pourcentage de perte du rendement est de l'ordre de 0,75 % pour le traitement M3 et de 0,04 % suite à l'application Mélange, alors qu'il était de 91,5 % pour le témoin M0.Cela nous permet de conclure que les traitements M3 et Mélange présentent une solution de rechange économiquement avantageuse (par rapport aux insecticides de synthèse) pour les producteurs de semences souhaitant stocker leurs semences dans l'attente d'un prix rémunérateur.

Le second essai (tableau 2) fut mené du 5 janvier au 4 juin 2001. Cette fois-ci le nombre de couples d'imagos lâchés par unité expérimentale fut 5.

D'une façon générale, le tableau 2 montre la même tendance que le tableau 1.

La dose de 30 g de poudre de *Maesa lanceolata* et la dose paysanne permettent une fois de plus de réduire considérablement la prolifération des insectes et, par conséquent, les pertes de poids des stocks sont négligeables. Le pourcentage moyen de ces pertes est 0,6 % pour le traitement M3 et 0,005 % pour l'application du Mélange. Le nombre d'imagos ayant émergé était de 1,13 (M3) et 0 (Mélange).

Dans la pratique, l'enrobage des graines en appliquant la dose de 30 g de poudre de *Maesa lanceolata* par kilogramme de graines signifie que, pour 100 kg de semences à conserver, le paysan aura besoin de 3 kg de poudre. À cette échelle relativement modeste, cela ne pose pas de problème. Pour obtenir 3 kg de poudre, le paysan devra abattre deux ou trois arbustes. *Maesa lanceolata* est encore une plante sauvage que l'on trouve actuellement dans les réserves forestières et aires protégées du Kivu. Si toutefois l'on souhaite prévenir l'abattage systématique et éviter la menace d'extinction des populations sauvages, il importera de domestiquer l'arbuste et de l'intégrer dans les agro-écosystèmes locaux des paysans.

Le problème se pose si l'on examine le cas de la « dose paysanne ». Nous avons vu que la brigade agricole des paysans de Katana avait découvert que l'incorporation d'une dose de 200 g de poudre de plantes mélangées à un kilogramme de graines de haricot, permettait de très bien maîtriser les bruches. Les deux essais que nous avons réalisés sur une année pleine nous ont conduits aux mêmes observations et conclusions. Or dans la pratique, une telle dose présente des difficultés. Un paysan souhaitant conserver

Tableau 2. Effet du poudrage graines de haricot sur le ravageur *Acanthoscelides obtectus :* résultats du second essai (6 mois ; 5 couples d'insectes par unité expérimentale)

			Variété + poids initial des graines					
			M'Mafutala (1 kg) n=1809 graines		VCB81012 (1 kg) n=1721 graines		Moyenne générale	
.	Dose (g)	Traite^{mnt}	P(%)	N	P(%)	N	P(%)	N
Tagetes minuta	0	T0	49,00	77,00	56,90	65,00	48,00	71,500
	10	T1	19,00	59,00	25,70	83,00	17,50	71,000
	20	T2	8,00	27,00	19,10	47,00	13,50	37,000
	30	T3	5,50	1,70	15,50	27,10	10,50	22,500
Agava americana	0	A0	40,00	81,00	61,50	91,00	55,75	91,000
	10	A1	29,00	41,00	26,70	72,00	27,53	56,500
	20	A2	6,00	8,71	2,70	27,00	4,35	14,570
	30	A3	2,00	1,49	1,65	7,00	1,82	4,245
Maesa lanceolata	0	M0	46,00	81,00	24,10	51,00	30,00	66,000
	10	M1	17,10	45,00	5,50	24,00	11,30	34,500
	20	M2	0,56	1,60	0,70	1,50	0,63	1,550
	30	M3	0,08	1,20	0,04	1,06	0,60	1,130
Mélange	200	MDP	0,005	0	0,005	0	0,005	0
SED			0,94	0,07	0,035	1,27		

Légende:

P(%) : pourcentage de perte de rendement
N : nombre moyen des imagos émergés après 4 mois de stockage
n : nombre initiale des graines
Mélange : « dose paysanne » composée des poudre de plusieurs plantes (utilisée au Kivu)
SED: Erreur standard d'une différence entre les moyennes des traitements

100 kg de graines devra fabriquer 20 kg de poudre ; pour obtenir les ingrédients du mélange de poudres requis, il devra récolter des plantes sur une surface de plus d'un hectare ! Il n'est pas facile pour un paysan du Kivu de pouvoir consacrer un hectare de ses terres à la culture des plantes insecticides.

Autres plantes insecticides

L'usage des plantes médicinales dans la lutte contre les ravageurs des denrées stockées est une pratique courante en Afrique noire. De nombreux chercheurs africains s'intéressant à l'amélioration et à la rationalisation des pratiques paysannes de conservation des stocks avec les produits locaux, se sont efforcés d'inventorier les diverses pratiques et d'en évaluer l'efficacité dans différentes zones agro-écologiques de l'Afrique. Giga et Chinwada (1993) ont ainsi observé au Zimbabwe que la dose de 0,1 kg de neem (farine de feuilles et graines) par kilogramme de graines conservées permettait de réduire significativement le nombre d'imagos émergés et le pourcentage de perte de poids. Autre exemple, en Afrique occidentale : l'apport de l'écorce pulvérisée de *Khaya senegalensis* à la dose de 50 g/kg de niébé ou de mil conservé, permet une réduction sensible du nombre d'insectes émergés et une réduction de la perte de poids allant jusqu'à 0,56 % (Gwinner *et al.*, 1991). Par ailleurs, nombre d'études menées dans la région des Grands Lac (Rwanda, Burundi, etc.) ont déjà porté sur l'efficacité et la rémanence de feuilles ou d'inflorescences fraîches ou séchées de quatre plantes (*Ocimum kilimandascharium, Iboza riparia, Chenopodium schraderanum, Capsicum frutensis*) sur l'oviposition des femelles, le taux d'éclosion des œufs et le pourcentage de mortalité des larves et imagos de la bruche. Ainsi une étude menée au Rwanda en 1987 a permis de constater que des quatre plantes, seule *Iboza riparia*, était efficace. Utilisée sous forme de poudre séchée (doses de 5 g/kg de graines de haricot) cette plante entraînait un pourcentage de mortalité supérieur à 70 % (Ukiricho,1987). Ces résultats corroborent les nôtres même si nous n'avions pas utilisé les mêmes plantes.

Il existerait plusieurs biopesticides naturels contre les ravageurs de stocks. Au Cameroun, Parth *et al.* (1990) ont démontré que *Ocimum suave* et *Cypressus sp.* protégeaient très bien les graines de niébé stockées pendant plus de quatre mois contre les dégâts causés par les bruches *Callobruschus maculatus* et *Acanthoscelides obtectus*. En Afrique de l'Est, le neem (*Azadiracta indica*) utilisé sous différentes formes constitue probablement le plus puissant insecticide végétal en cours de promotion par les scientifiques. Dans la région des Grands Lacs, *Ocimum sp* serait l'équivalent du Neem dans la protection du haricot contre les bruches.

Il faut noter cependant que toutes ces plantes performantes ne sont pas distribuées équitablement dans les biotopes et écosystèmes de l'Afrique. Par ailleurs, certaines plantes s'adaptent difficilement lorsqu'on les introduit dans un nouveau milieu qui est écologiquement différent du milieu d'origine (biotopes préférentiels). Une façon de contourner cet obstacle écologique peut être de chercher, à tout point de la terre, quels biopesticides locaux peuvent servir de substitut aux pesticides de synthèse ou pour remplacer des biopesticides performants mais importés d'ailleurs.

Pour ce qui est de la maîtrise des bruches du haricot, *Maesa lanceolata* s'avère être une solution fort adéquate répondant aux préoccupations évoquées précédemment. Cette plante est localement trouvable au Kivu. Le fait qu'elle se reproduit par boutures et par graines présente un double avantage au niveau de la propagation de ce qui semble, actuellement, être l'insecticide végétal le plus puissant au Kivu.

CONCLUSION ET SUGGESTION

Nos recherches avaient pour objectif de connaître la dose optimale d'application de certaines poudres de plantes médicinales pour conserver des graines de haricot, notamment des farines granuleuses d'*Agava americana, Maesa lanceolata* et *Tagetes minuta*. Un deuxième objectif était de vérifier l'efficacité de la « dose paysanne » employée localement pour protéger les stocks contre les bruches du haricot emmagasiné.

Les résultats de nos travaux nous ont permis de tirer les conclusions suivantes :

- Les poudres de *Maesa lanceolata* réduisent significativement l'émergence des imagos dans les stocks de haricots et font ainsi baisser le pourcentage de perte de poids. Nous avons vu, en effet, qu'à des doses d'application de 20–30 g/kg de graines de haricot conservé pendant cinq mois ou plus, les poudres de *Maesa lanceolata* ralentissent considérablement le développement de la population des charançons. Le nombre d'imagos émergés a été de 1,13 au deuxième essai et de 2,65 au premier, différence qu'il faut comparer au résultat du témoin M0 du premier essai, à savoir 194,5 imagos. L'amoindrissement du pourcentage de perte de poids était de l'ordre de 0,75 % (1er essai) et 0,6 % (2ème essai).
- Le traitement par l'application de la dite « dose paysanne »—mélange de plusieurs plantes que l'on appliqué à raison de 200 g de poudre par kilogramme de graines—est très efficace contre les bruches.

Nous reconnaissons que nous n'avons pas encore pu mettre en évidence ni expliquer les comportements et les réactions des ravageurs face aux différentes variétés de haricots et face aux doses croissantes de poudres des plantes. De même, les mécanismes d'action en jeu qui font que les poudres freinent le développement normal des populations de charançons sur le haricot stocké constituent encore un domaine à élucider.

La recherche est donc mise au défi d'isoler puis de caractériser les principes actifs de *Maesa lanceolata*, qui, une fois déterminés, devraient pouvoir servir à la fabrication de biopesticides simples, moins coûteux, biodégradables et utilisables par le petit producteur souhaitant mieux protéger ses graines stockées contre les ravageurs.

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