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Field Management of Bruchids on Beans using selected Phytochemicals, Insecticides and Entomopathogen

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Abstract

The effectiveness of selected synthetic insecticides, phytochemicals and an entomopathogen against pod sucker-, pod borer- and bruchid-damage on beans was determined in the field. Beans were sown at a spacing of 30 cm by 10 between and within rows in 2x4 m-sized plots. Nine treatments, including the controls were evaluated. Phytochemicals included crude extracts of *Nicotiana tabacum, Phytolacca dodecandra, Tagetes minuta and Capsicum frutescens* and were applied as unitary or cocktail formulations. Synthetic insecticides were Cypermethrin 5% EC and Fenitrothion 50% EC, while *Beauveria bassiana* was the entomopathogen. The controls were untreated beans. Application of the treatments commenced at pod filling stage, and a spray regime of once a week was maintained for five weeks. Damage due to pod suckers and pod borers were determined. Similarly, to determine the effect of the treatments on bruchid damage harvested beans were processed into 400-g working samples, and each was placed in 500-ml polystyrene bottles and incubated at ambiance until there was no more bruchid emergence in the laboratory. Bruchid load carry-overs from the field into storage were determined at 34 and 41 emerged adults during 1st and 2nd seasons, respectively. Efficacies of the different treatments varied significantly ($P<0.05$) in reducing pod sucker, pod borer and bruchid damage on beans. Untreated beans were the most damaged. Cypermethrin-treated beans were the least damaged and an 8-10 fold reduction in bruchid infestation was observed. Tobacco was the most effective botanical. The earliest and highest peak of bruchid emergence was in the untreated beans, unlike in the Cypermethrin- and tobacco-treated beans. A positive and significant relationship occurred between pod sucker and borer damage and *A. obtectus* infestation levels.

Key words: Beans, pests, bruchids, *Acanthoscelides obtectus,* storage, management

Introduction

Bean storage over long periods, especially, at small-scale subsistence farming levels in Uganda, is limited due to bruchid infestation that results in heavy losses. To avoid excessive losses, most farmers are forced to sell off surplus grain immediately after harvest, and this unfortunately, often coincides with the time when prices are lowest (Silim et al., 1991). This scenario negates motivation to increase production as well as store for longer periods, and hence the vicious cycle of low dietary intake of cheap proteins of high biological value.

Although it is generally known that pest infestation of beans starts in the field, there is little information on field management methods, apart from early harvest and subsequent phytosanitation to reduce storage infestation (van Huis, 1991). The available bruchid management methods only target beans in storage with little attention to field infestation. The methods include vegetable oil (Silim-Nahdy and Agona, 1996), hermetic storage (van Huis, 1991; Kyamanywa *et al.,* 1999), solarisation (Agona and Silim-Nahdy, 1998), sunning and sieving regimes (Silim-Nahdy and Agona, 1996), contact insecticides and fumigants (Schoonhoven and Cardona, 1986; NRI, 1991).

There is paucity of information on the relationship between damage due to post-podding pests (pod suckers and borers) and bruchid damage. Silim-Nahdy (1995) observed reduced field bruchid load in storage when Cypermethrin 5% EC was applied routinely to control pod borers and suckers on pigeonpea, no conclusive or similar studies, however, have been conducted on beans to merit field management. Sadawarte (1997) reported the use of insecticides and biorationals against aphids, pod sucking bugs and borers, no such protocols, however, are available for field management of stored products insect pests.

An attempt was therefore made to evaluate different pest management strategies that had either proven effective in reducing damage by bruchids on other legumes in storage or in the field (Silim-Nahdy, 1995; Aloci, 2000). The study focused on establishing bruchid carry-over from the field into storage, and determining the efficacies of selected treatments against bruchids. The study was conducted on-station for two seasons.

Materials and Methods

Treatment formulations

The common bean variety, K20, was planted in 2x4 m-sized plots at spacings of 30 cm and 10 cm between and within rows, respectively. To minimise phytochemical/insecticide/spore drift between neighbouring plots, a guard row of maize was sown around the plot. The plots were arranged in a randomised complete block design (RCBD), with each replicated four times. The following treatments were tested:

- i. *Phytolacca dodecandra*
- ii. *Tagetes minuta*
- iii. *Nicotiana tabacum*
- iv. Cypermethrin 5% EC
- v. Fenitrothion 50% EC
- vi. *Beauveria bassiana*
- vii. Fermented concoction of *P. dodecandra, T. minuta, Capsicum frutescens,* bean ash filtrate, soap and cow urine (Urine based)
- viii. Fermented concoction of *P. dodecandra, T. minuta, C. frutescens,* bean ash filtrate, soap and cow urine (Water based)
- *ix. Control (no treatment application)*

Phytochemicals were used either as fresh products of single plants or as fermented concocted products of more than one-plant species formulations. Formulations of crude extracts from single plants were prepared by mixing 1-kg pounded leaves in 2 litres of water and then filtering using a fine cloth mesh to yield "concentrated" spray formulations. The 'concentrated' extracts were diluted in 4 litres of water prior to application.

Fermented concoctions were prepared by mixing 1-kg pounded leaves of *P. dodecandra* and *T. minuta,* 0.25 kg of *C. frutescens* (fruits), 0.5 kg of ash in either 5 litres of cow urine or water. The compound mixtures were fermented in 20-litre plastic containers for 1 week. The cocktail solution was filtered through a sieve made of cotton cloth and 250 ml of liquid soap was added. The filtrate was stored under ambient conditions in 5-litre plastic containers and used when required.

The synthetic insecticides used included Cypermethrin 5% EC and Fenitrothion 50% EC, which were applied as, recommended by the manufacturers, i.e. 2 litres per hectare.

A suspension of *B. bassiana* spores in water and soap was obtained by mixing 2 kg of coarse maize bran containing the fungal spores in 4 litres of water. The mixture was allowed to settle for 24 hours after which it was filtered and 250 ml of soap added. The approximate number of spores per litre was determined by use of Neuabauer haemocytometer and was estimated at 1.18×10^{10}.

In all the treatments 250 ml of liquid soap was added into the spray formulations as a surfactant prior to being applied.

Treatment application

Application of the above treatments was initiated at pod filling stage (i.e. 62 days after planting), and was continued on a weekly basis four more times. A 15-litre Knapsack sprayer was used to apply the various chemicals. The sprayer was thoroughly cleaned with water and soap prior to being re-filled again with another formulation for application.

The beans were harvested on the 97th day after planting, when the pods were partially dry. During harvest, the pods in each plot were hand picked and sorted into pod damaged by sucking bugs and/or pod borers and, the non-damaged. Pods damaged by bugs were wrinkled and with few small seeds, and bored pods had open holes, partially eaten seeds, and remnants of cocoons.

Harvested pods from each plot were dried separately in the sun until the moisture content equilibrated between 12 and 13%. The pods were threshed, winnowed and the grains from each replicate bulked and sample divided to obtain 400-g working samples. The working samples were placed in 500-ml polystyrene jars fitted with perforated lids, and incubated under prevailing ambient conditions. The cultures were monitored for bruchid emergence during the entire period. The bruchids that emerged were extracted, identified, counted and discarded. This was continued until there was no further emergence. Percentage of damaged seeds due to bruchids was determined.

The data were analysed using 2-way ANOVA of the MSTAT-C statistical package. Two means were declared significantly different when the difference between them was greater than twice the standard error difference (SED).

Results

The only bruchid species that emerged in all the treatments was *Acanthoscelides obtectus* Say (Coleoptera: Bruchidae). There were significant differences ($P<0.05$) between treatments in controlling the number of adult *A. obtectus* that emerged. The highest emergence was observed in the controls and the least in the Cypermethrin-treated beans during both seasons (Tables 1 and 2). Among botanicals, tobacco-treated beans were the least damaged, and had the lowest number of adult bruchids that emerged. Tagetes as a single formulation, unlike tobacco was the least effective against the target pests among the botanicals. The performance of tobacco in reducing bruchid damage was rated second to Cypermethrin. The efficacies of other treatments were better than the control, and had reduced adult emergent numbers and seed damage.

The emergence patterns of *A. obtectus* from cultured beans varied between the different treatments applied. The earliest and highest amplitude of emergence was observed in the controls, and the lowest and shortest amplitude was on the Cypermethrin-treated beans (Fig. 1). The time difference between the two peaks was about 10 days. Generally, peak emergence period was delayed in the best performing treatments.

The effects of Fenitrothion, *B. bassiana* and *P. dodecandra* in reducing bruchid damage levels were not significantly different ($P>0.05$) from that of tobacco during the 1st season. During the 2nd season the effectiveness of Fenitrothion against bruchids was markedly reduced. The urine-based fermented concoction yielded better results than the water-based in reducing bruchid, pod borer and pod sucker damage level of beans.

Field bruchid load carry-over into storage was determined at 34 and 41 emergent adults during 1st and 2nd seasons, respectively. The numbers were derived

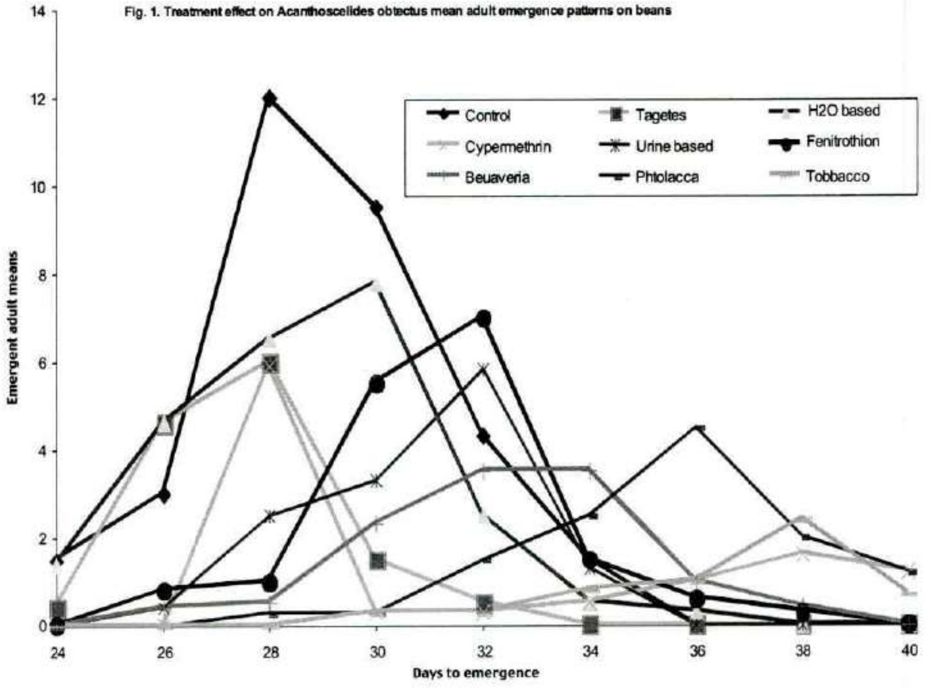
Table 1. Means of A. obtectus emergent adult number, percent seed damage and percent pod damage due to different treatment application (1st season)

Treatments	Emergent adults (Mean ± SE)	Seed damage (%) (Mean ± SE)	Pod damage (%) (Mean ± SE)
Control	34.0 ± 2.3	4.0 ± 0.3	8.7 ± 0.2
Water concoction	24.5 ± 2.2	2.4 ± 0.2	7.0 ± 0.2
Tagetes	22.0 ± 1.3	2.3 ± 0.2	6.6 ± 0.4
Urine concoction	14.0 ± 0.9	1.5 ± 0.1	6.2 ± 0.5
Phytolacca	11.5 ± 1.7	1.4 ± 0.1	5.6 ± 0.2
B. bassiana	10.5 ± 0.7	1.6 ± 0.1	6.1 ± 0.1
Fenitrothion	9.5 ± 0.7	1.4 ± 0.1	4.9 ± 0.1
Tobacco	6.3 ± 0.9	1.1 ± 0.2	5.5 ± 0.2
Cypermethrin	4.0 ± 1.0	0.4 ± 0.1	4.8 ± 0.2
CV (%)	19.49	19.35	8.42
SED (24 d.f.)	2.09	0.50	0.76

Table 2. Means of A. obtectus emergent adult number, percent seed damage and percent pod damage due to different treatment application (2nd season)

Treatments	Emergent adults (Mean ± SE)	Seed damage (%) (Mean ± SE)	Pod damage (%) (Mean ± SE)
Control	41.3 ± 4.3	3.6 ± 0.4	6.5 ± 0.4
Water concoction	27.3 ± 1.4	2.4 ± 0.2	5.1 ± 0.3
Tagetes	25.0 ± 1.0	2.0 ± 0.1	4.7 ± 0.3
Fenitrothion	22.8 ± 2.1	1.9 ± 0.2	4.8 ± 0.2
Urine concoction	21.5 ± 0.7	1.8 ± 0.1	4.7 ± 0.1
B. bassiana	*17.5 ± 1.0*	*1.6 ± 0.1*	*4.6 ± 0.1*
Phytolacca	14.3 ± 1.3	1.2 ± 0.1	3.4 ± 0.2
Tobacco	11.8 ± 0.9	1.0 ± 0.1	4.0 ± 0.1
Cypermethrin	4.8 ± 1.3	0.3 ± 0.1	3.2 ± 0.1
CV (%)	18.85	20.00	9.83
SED (24 d.f.)	2.74	0.51	0.65

Figure 1. Treatment effect on *Acanthoscelides obtectus* mean adult emergence patterns on beans



from the total number of adult insects that emerged from the untreated beans (the controls).

Treatment effects on pod sucker and pod borer damage levels of beans yielded similar results like the ones achieved on bruchid management (Tables 1 and 2). There was a highly significant ($P<0.05$) and positive relationship between *A. obtectus a*dult emergence numbers and pod damage due to suckers and/or borers. The correlation coefficients (r) were determined at 0.93 ($n= 30$) and 0.89 ($n= 30$) during 1[st] and 2[nd] seasons, respectively.

Discussion

The study has confirmed bean infestation by *A. obtectus* in the field and its continuation in storage (NRI, 1991; van Huis, 1991). This was demonstrated by the F_1 generation that emerged from the untreated beans. Huignard (1979) and Thiery and Jarry (1985) noted that *A. obtectus* infestation is of field origin, although cross infestation may occur during storage. Farmers, however, are only aware of incipient infestation during storage, especially when the resident bruchid populations are seen flying around and grains become weeviled (Silim *et al.*, 1991).

The application of the different treatments and the subsequent reduction of bruchid damage levels as well as carry-over population from the field strongly suggest the need for field management with appropriate treatments. Field infestation is undeniably the main source of subsequent infestation of stored beans, and thus must be controlled. Southgate (1978) and Silim-Nahdy (1995) observed that field chemical application at late podding stages reduced the number of weevils that emerged during storage.

It is observed that the use of chemical dust admixtures only controls existing bruchid populations by contact and thus inherent infestation may escape. Secondly, farmers apply such treatments only when infestation becomes visible, and this coincides with damage inflicted by developing larvae as a result of field infestation. The need for phosphine fumigation therefore becomes desirable for the eradication of both incipient and actual bruchid infestations of stored beans. Under subsistence farming level however, fumigation is considered inappropriate because of the high cost, level of technical competence and toxicity problems. Alternative methods of control of field load carry-overs could therefore entail solarisation treatment, but this method is only good for grains but not seed.

Pre-harvest infestation by bruchids may often cause only limited damage, but has serious implications on storage duration. This is because insects multiply very rapidly within a short time when transferred into storage, and this coupled with poor storage sanitation, results in high damage levels. Heavy losses occur within 4-8 weeks of storage (Taylor, 1981; Dobie, 1981).

The beans that were treated with Cypermethrin 5% EC, tobacco, phytolacca, Fenitrothion 50% EC and Beauveria, unlike those that received no treatment, had reduced bruchid damage. The efficacies of the different treatments however, varied depending on the source of the of the active ingredient. For instance Cypermethrin-treated beans were the least attacked and this was demonstrated by reduced emergent adult numbers, low damage levels and increased development period for the few adult *A. obtectus* that emerged. Silim-Nahdy (1995) observed reduced bruchid damage levels when Cypermethrin was applied to control pod suckers and borers infesting pigeonpea in the field. The use of synthetic insecticides is however, limited under small-scale subsistence agriculture because of high cost, lack of technical expertise in application and handling of chemicals, stockists' abuse, unavailability, user and environmental concerns.

Tobacco although less effective than Cypermethrin, also performed fairly well against the bruchids. Earlier work by Agona *et al.* (un published) showed that when used as an admixture, tobacco powder extended the storage duration of stored beans to more than 4 months with insignificant bruchid damage. Ofuya (1986) used tobacco powder as admixture against *Callosobruchus maculatus* and noted reduced egg laying and hatchability by the pest on cowpeas. There is however, paucity of information on the toxicological levels of botanical admixtures on stored grains, and this may restrict usage. Since phytochemicals are organic in nature, they are assumed easily biodegradable, and thus their field application may greatly reduce the problem of contamination. The relatively poor performance by other botanicals may be attributed to insufficient dosage rates both in quantity and ill-defined spray regime.

Fecund *Acanthoscelides obtectus* females are known to lay eggs on mature and ripening bean pods especially, those that are shattered or partially opened (Southgate, 1978). The 1st larval instars upon hatching have to penetrate the seeds immediately otherwise they die due to desiccation or other infringes of nature (Schoonhoven and Cardona, 1986). It is envisaged that the timing of phytochemical and insecticide application should synchronise with oviposition, hatching and 1st instar larval penetration into seeds to allow contact.

Considering the efficacy of *B. bassiana*, the results obtained against bruchids in the field are promising. The major problem with entomopathogens, however, lie in formulation, dosage rates, stability under environmental conditions, and insufficient information on their ability as contaminants of stored grains or seeds (Oduor, per. comm.). Nankinga (1999) observed reduced damage levels of banana corms by *Cosmopolites sordidus* when *B. bassiana* was applied as treatment.

The results strongly suggest that bean pod damage by boring lepidopteran larvae *(H. armigera and/or Maruca testulalis)* and sucking bugs (*Clavigralla* spp.) encouraged field infestation by *A. obtectus*. This was confirmed by the highly significant and positive relationship between pod damage and *A. obtectus* infestation levels. Their feeding punctures possibly act as oviposition sites that provide anchorage to the loosely laid eggs in the pods. There is no literature to confirm this observation thus more investigation on this aspect is needed.

Conclusions and recommendations

The study has confirmed that the most common bruchid that infest beans in the field is *A. obtectus*, and thus the need for reduction of load carry-over into storage. There is strong empirical evidence that associates damage levels by pod borers and suckers to *A. obtectus* infestation rates and thus management of bean pod pests recommended. Field application of some treatments, especially, Cypermethrin 5% and tobacco was very effective in reducing both field infestation and subsequent damage levels in storage. Their application did not only reduce the population of emergent *A. obtectus* adult but also delayed their development periods.

It is recommended that the promising treatments especially Cypermethrin 5%, tobacco and phytolacca are validated on-farm under farmer field and storage managed conditions. More studies are required on dosage rates and spraying regimes of other less effective but promising botanicals. It is recommended that strict storage sanitation and other forms of treatments e.g. tobacco admixture and solarisation, are practised to avoid cross infestation of field treated beans or to destroy carry-over populations from the field. A potential spin off from this study is application of similar treatments on bruchids that infest cowpeas and pigeonpeas both in the field and in storage.

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