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Kairomone trapping system for delivery of *Beauveria bassiana* to control the banana weevil

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Abstract

Field studies were conducted to determine banana weevil attraction to processed banana tissues that could then be used at delivery sites for the entomopathogen *Beauveria bassiana*. Tested materials included pounded corm or pseudostem and chopped corm or pseudostem of (cv Mpologoma, AAA-EA and Kayinja, AAB), which were placed on top of the soil and buried 5 cm below the soil surface. Processed banana materials placed at the soil surface captured 2.0 – 2.7 weevils/trap, with no significant differences among the traps, and were more attractive than split pseudostem traps. By contrast, material buried 5 cm below the soil surface captured only 0.1 – 0.5 weevils/trap, and were less attractive than the split pseudostem traps. Kayinja chopped tissues captured significantly more weevils than the rest of the processed banana tissues. There were no significant differences between the two test cultivars or the test plant parts. Although buried banana materials had been reported elsewhere as highly attractive to banana weevils, our results suggest that burying processed banana tissues actually lowers their ability to attract banana weevils. Moreover, the realized attraction levels of the processed tissues placed at the soil surface may not be sufficient for their recommendation as appropriate for the delivery of entomopathogens, given the extra labor required in comparison to conventional pseudostem trapping. However, efforts to improve attractivity of the banana tissues, such as integration with other weevil trapping strategies (e.g. use of pheromones) should focus on placement of the tissues at the soil surface, instead of burying them. This might result in synergistic effects thus improving their ability to aggregate adult banana weevils under field conditions.

Key words: *Cosmopolites sordidus, Musa* spp., pseudostem traps

Introduction

The banana weevil *Cosmopolites sordidus* (Germar) (Coleoptera:Curculionidae) is the major insect pest of bananas in Africa (Sikora *et al.*, 1989, Gold *et al.* 1999). The larvae bore in the corm and lower pseudostem resulting in plant loss, reduced yields and shortened plantation life (Sikora *et al.*, 1989; Rukazambuga *et al.*, 1998; Gold *et al.*, 2001). The larvae are often found beneath the soil surface deep within the plant, making them largely inaccessible to arthropod natural enemies. The adults, on the other hand, are free-living, nocturnally active and positively hydrotrophic, and normally found around the banana mats and residues (Gold *et al.*, 2001). In developing integrated pest management strategies against this insect, it is therefore easier to target the adult rather than the larval stage.

The entomopathogenic fungus *Beauveria bassiana* has demonstrated great potential to control the banana weevil (Nankinga, 1999; Nankinga and Moore, 2000; Kaaya *et al.*, 1993; Godonou, 1999), capable of causing 50 – 100% adult weevil mortality in 14 days under laboratory conditions and 50 – 60% when applied under split pseudostem and disk on stump traps respectively in the field (Nankinga, 1999). The fungus, however, requires an effective and affordable delivery system that can be used by the resource limited small-scale banana farmers. Pseudostem trapping which has been tested for *B. bassiana* delivery, is associated with high material and labour requirements that may be unrealistic to the resource poor farmers (Ndege *et al.*, 1995; Gold *et al.*, 2002), and only 5 – 15% of the weevils may come to pseudostem traps at any given time (Mitchell, 1978). Bakyalire (1992) reported that trap type: clone, age, size; location and number of traps; soil moisture and time left between setting and checking traps for captured weevils, are some of the factors that influence trap catches. Although corm-based disk on stump traps are more attractive to banana weevils than pseudostem traps, they are fixed in space, with a single harvested plant providing only one trap, compared to the many pseudostem traps that come from one plant (Bakyalire, 1992; Gold *et al.*, 2002). In addition, disk on stump trapping is not applicable in newly established fields where no harvesting has been done. Attraction of phytophagous insects to the host plant depends on the amount of volatiles being emitted by the plant for orientation, as well as other chemical and physical factors that affect feeding and breeding (Bernays and Chapman, 1994). Budenberg and Ndiege (1993) found that both male and female weevils were attracted to banana plant volatiles, and they suggested that weevil orientation responses were probably related to finding food rather than oviposition sites. Banana residues have been reported to attract more banana weevils than standing plants, and that attraction increases with age of the residues (Masanza, 2003).

Semiochemicals have been suggested as a means of aggregating banana weevils at entomopathogen-baited traps (Budenberg *et al*., 1993; Gold *et al*., 2001). In Kenya, Lux (pers. comm.) observed that kairomone traps made with pounded pseudostem material and buried in the soil could attract high numbers of banana weevils. He suggested that such traps could be used for delivery of entomopathogens such as *B. bassiana and M. anisopliae* to form "killing nodules". From the work done in Kenya, there is hardly any documentation of the source-cultivar or clone of the pounded materials, and the depth at which the materials should be buried. Furthermore, attractivity of the buried pounded banana material was never evaluated against any known check (e.g. standard pseudostem trap).

The objectives of this study were therefore, to determine the attractivity of traps made from various forms of banana tissues in comparison with the standard split pseudostem trap. If successfully developed, this trapping system would then be used in the delivery of *B. bassiana* for the control of the banana weevil.

Materials and methods

Experiments were conducted at the Kawanda Agricultural Research Institute, (0°25'N, 32°32'E, 1190 m above sea level), 13 km north of Kampala, Uganda, with 12-hour day length throughout the year. The soil is an isohyperthermic Kandiudalfic Eutrodox (USDA taxonomy) with high water holding capacity, medium acidity (pH 5.9-6.3), low organic matter content, deficient in nitrogen and phosphorus (McIntyre *et al*., 2001). Rainfall at the site averages 1224 mm annually and is of bimodal distribution with the first season lasting from March to June and the second season from August to December (Kayuki and Wortmann, 2001).

The study consisted of field-testing processed banana tissues as weevil trapping materials in an established banana trial planted with highland banana cultivars Namaliga (AAA-EA) and Ndibwabalangira (AAA-EA). The field was mulched with banana leaf trash and dry elephant grass. The study consisted of two experiments. Experiment one was conducted in May 2003 in which processed banana tissues for weevil trapping were buried 5 cm under the soil. It involved 13 plots with 42 banana mats each, spaced in a 3 x 3 m arrangement. Weevil population was estimated in the experimental field prior to treatment allocation by pseudostem trapping (3 traps per mat; 9 mats per plot). Processed banana tissues used as trapping material included (1) fresh-pounded corm, (2) chopped corm, (3) pounded pseudostem and (4) chopped pseudostem from the susceptible cultivar Mpologoma (AAA-EA) and from the resistant cultivar Kayinja (ABB). Thus, a total of eight processed banana tissues were evaluated. Pounding of the tissues was done with a local mortar, while chopping was done using a machete. Kairomone traps were made from 1 kg of the various processed tissues, estimated to be equivalent to the weight of a 25 cm-length split pseudostem trap. These were then placed in a plastic bowl (20 cm-diameter x 9 cm-depth) and buried at 5 cm beneath the soil surface near a banana mat. The bowl was used to facilitate ease of data collection. Eight treatments (i.e. processed tissue traps) and one control trap (bowl containing soil) were assigned to the selected nine mats in each plot (i.e. 1 trap per mat), on which weevil density had been estimated, and were laid in a Randomized Complete Block Design (RCBD), replicated 13 times. One mat represented an experimental plot. The tissues were examined after 7 days and the number of weevils recorded and withdrawn from the plot. The tissues were then, placed back in the same location and examined a second time 7 days later.

The second experiment was conducted in December 2003 and involved the same processed banana tissues (as used in experiment one) as weevil trapping materials, but this time, were placed at the soil surface. It was conducted in the same field utilizing 10 plots. Weevil population was estimated again in the experimental field prior to treatment allocation by pseudostem trapping (2 traps per mat; 9 mats per plot). Processed tissue traps were made from 1 kg of the freshly processed tissues placed on the soil surface and covered with mulch near the selected banana mats at which weevil density had been estimated. Treatments were assigned in a Randomized Complete Block Design (RCBD) and replicated 10 times. Traps were examined at 3-day intervals to minimize weevil dispersal from the tissues before recording. On each sampling occasion, number of banana weevils collected from the traps was recorded; banana tissues placed back on same location and the collected weevils taken away from the field. The experiment was run for 12 days, the period after which the trapping materials had dried up.

Data for the two experiments were analyzed separately since they had varying sampling regimes (i.e. 7- and 3-day intervals). In both cases, analysis was done using two-factor ANOVA on SAS statistical package (SAS Institute Inc., 1990). Treatment means were separated using Least Significant Difference (LSD) option.

Results

Pre-treatment pseudostem trapping conducted in experiment-one revealed moderate weevil population with mean trap captures of 1.0 – 1.7 weevils/trap. It was also observed that processed banana tissues buried 5 cm under the soil captured less than one weevil per trap on average (range 0.08 - 0.54 weevil/trap) (Table 1), and were less attractive than the split pseudostem traps (Fig. 1). Of the processed banana tissues tested, chopped corm tissues of Kayinja captured significantly ($P < 0.05$) higher banana weevils than the rest of the tissues. In general, however, there were no significant ($P > 0.05$) differences between weevil attractivity to the two test cultivars – Kayinja and Mpologoma or between the two plant parts – corm and pseudostem. Table 2 shows trap catches for the two sampling occasions i.e. at 7 days and 14 days, respectively, when the tissues were buried under the soil. Corm tissue based traps of both cultivars caught more weevils after 7 days than after 14 days. By contrast, pseudostem tissue traps were more attractive at 14 days than at 7 days.

Pre-treatment pseudostem trapping in experiment-two still revealed moderate population with trap captures of 1.5 – 1.8 weevils/trap. Processed banana tissues (treatment traps) placed at the soil surface captured an average of 2.0 - 2.7 weevils/trap (Table 3). The processed banana tissues traps in this environment were more attractive than the split pseudostem traps (Fig. 2). Unlike the buried tissues, there were no significant ($P>0.05$) differences in weevil attraction among the processed banana tissues. No significant ($P>0.05$) differences were observed between the test cultivars and the plant parts in this environment, as observed with the buried tissues. There was a general decrease in the number of weevils captured per trap from the start to the last sampling date, with the traps capturing the highest number of weevils at the first sampling datae than the subsequent dates. Some of the trapping materials such as Kayinja chopped pseudostem and Mpologoma pounded pseudostem however had alternating trap catches over time

Discussion

This study revealed that banana weevils are attracted to processed banana tissues. Although Bakyalire (1992) noted that clone of the banana from which trapping material has been obtained affects trap captures, results from these studies showed no significant difference in weevil catches of processed banana tissues of the tested cultivars "Mpologoma" (AAA-EA) and "Kayinja" (ABB) under field conditions. Contrastingly, other studies have reported varying weevil captures for traps made from various banana clones. For instance, Seshu Reddy *et al.* (1993) showed that traps made of cooking bananas are more attractive to the weevils than traps made of dessert bananas. Abera *et al.* (1999) however, observed that weevils were equally attracted to growing susceptible and resistant cultivars, which concurs with the present findings. These variations in weevil capture could be attributed to the complex behaviour of the banana weevil and could also be based on individual cultivar characteristics rather than characteristics of a given group of cultivars.

The study further revealed that processed banana tissues placed at the soil surface attracted more weevils than tissues buried under the soil, which were also found less attractive than the conventional split pseudostem trap. This could be attributed to the ability of volatiles from the tissues to easily diffuse to the weevils and cause attraction. Thus, volatiles from tissues placed at the soil surface perhaps diffuse at faster rates to create a concentration gradient strong enough to cause weevil attraction from the banana mats. Conversely, burying the tissues under the soil could have resulted in weak diffusion of the volatiles that could not significantly attract weevils, a situation that is more likely to prevail in soil types that are subject to compaction and surface crusting. In addition, lower weevil catches in the buried tissue traps could be attributed to the masking of volatiles from the tissue traps by those from other sources in the field, such as mulch, banana residues and the growing host plants themselves, thus interfering with weevil response to the traps. In relation to this aspect, Price (1993) and Rukazambuga (1996) found that mulching reduces trapping efficiency, and Price (1993) postulated that decomposing mulch releases volatile chemicals that mask either the attractive substance(s) or in some other way interferes with normal weevil responses to stimuli given off by traps.

The observed higher weevil captures of the tissue traps placed on the soil surface compared with split pseudostem traps under field conditions perhaps imply that tissue processing increased the rate of volatile emission from the tissues compared with volatile emission rates for an intact split pseudostem trap. In general however, the realised low numbers of weevils aggregated by processed banana tissue traps in this study may not be sufficient for their recommendation as appropriate for the delivery of the entomopathogen *B. bassiana,* given the extra labour required in comparison to the conventional split pseudostem trapping. Nevertheless, it is probable that modification of the soil surface-placed processed tissue traps would result in a greater proportion of the weevil population aggregated at the trap site. This may be achieved through proper covering of the tissues to minimise drying and/or by combining the processed tissues with other weevil trapping strategies, such as pheromone trapping, which may result in synergistic effects. Tinzaara *et al.* (2002, 2003) observed higher weevil response to fermented banana tissues combined with an aggregation pheromone under the laboratory olfactometer, which suggested synergism between the pheromone and banana tissues. This however remains to be ascertained under more comprehensive field studies. In a field study involving a combination of various

Table 1. Overall mean number of banana weevils captured by processed banana tissues buried at 5cm under the soil near banana mats at Kawanda Research Station, May 2003

Cultivar	Processed material used	Mean no. of weevils ± S.E
Kayinja	Chopped corm	0.54 ± 0.20
	Chopped pseudostem	0.23 ± 0.10
	Pounded corm	0.12 ± 0.06
	Pounded pseudostem	0.13 ± 0.13
Mpologoma	Chopped corm	0.17 ± 0.10
	Chopped pseudostem	0.08 ± 0.08
	Pounded corm	0.39 ± 0.15
	Pounded pseudostem	0.39 ± 0.18

Table 2: Average number of weevils captured by processed banana tissues buried at 5 cm under the soil at 7 days and 14 days at Kawanda Research Station, May 2003

Cultivar	Processed material used	Mean ± S.E	
		7 days	14 days
Kayinja	Chopped corm	0.67 ± 0.36	0.42 ± 0.19
	Chopped pseudostem	0.08 ± 0.08	0.39 ± 0.18
	Pounded corm	0.23 ± 0.12	0.00 ± 0.00
	Pounded pseudostem	0.00 ± 0.00	0.25 ± 0.25
Mpologoma	Chopped corm	0.33 ± 0.19	0.00 ± 0.00
	Chopped pseudostem	0.08 ± 0.08	0.08 ± 0.08
	Pounded corm	0.54 ± 0.24	0.23 ± 0.17
	Pounded pseudostem	0.31 ± 0.17	0.46 ± 0.31

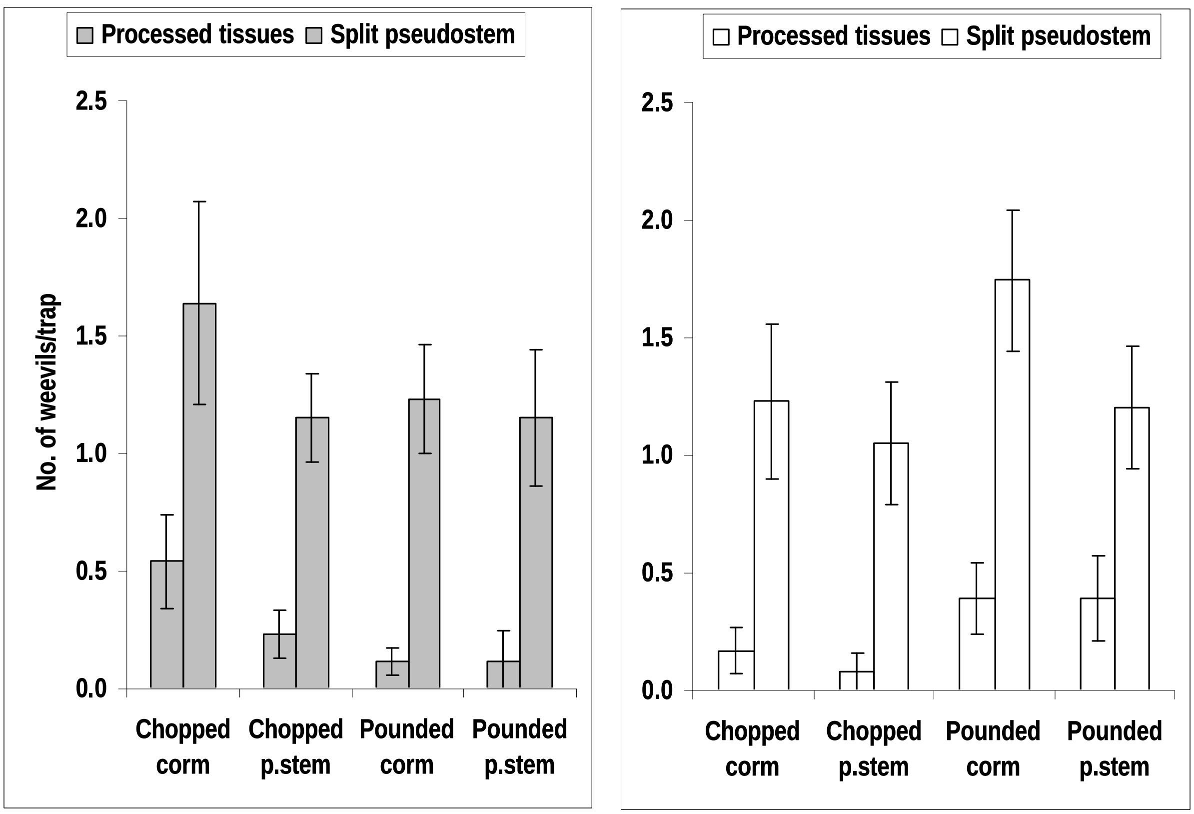

Figure 2. Average number of banana weevils captured by processed banana tissue traps buried at 5 cm under the soil,compared with conventional pseudostem trap captures

forms of banana traps with *B. bassiana*, with the fungus applied around the traps, infected weevils were captured 3 m away from the *B. bassiana* treated traps (Tumuhaise, unpubl. data). Thus, such traps to which weevils aggregate and later disperse may be more beneficial, than those that retain the weevils, in the dissemination of *B. bassiana* as the dispersing infected weevils would transmit the fungus to health individuals within the habitat. There is evidence that infected weevils can transmit *B. bassiana* to health individuals (Nankinga, 1999; Schoeman and Schoeman, 1999). In addition, banana weevils infected with *B. bassiana*

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Table 3. Overall mean number of banana weevils captured by processed banana tissues placed on the soil surface near banana mats at Kawanda Research Station, December 2003

Cultivar	Processed material used	Mean no. of weevils ± S.E
Kayinja	Chopped corm	1.97 ± 0.23
	Chopped pseudostem	2.35 ± 0.34
	Pounded corm	2.73 ± 0.43
	Pounded pseudostem	2.40 ± 0.28
Mpologoma	Chopped corm	2.25 ± 0.28
	Chopped pseudostem	2.68 ± 0.44
	Pounded corm	2.15 ± 0.37
	Pounded pseudostem	2.50 ± 0.27

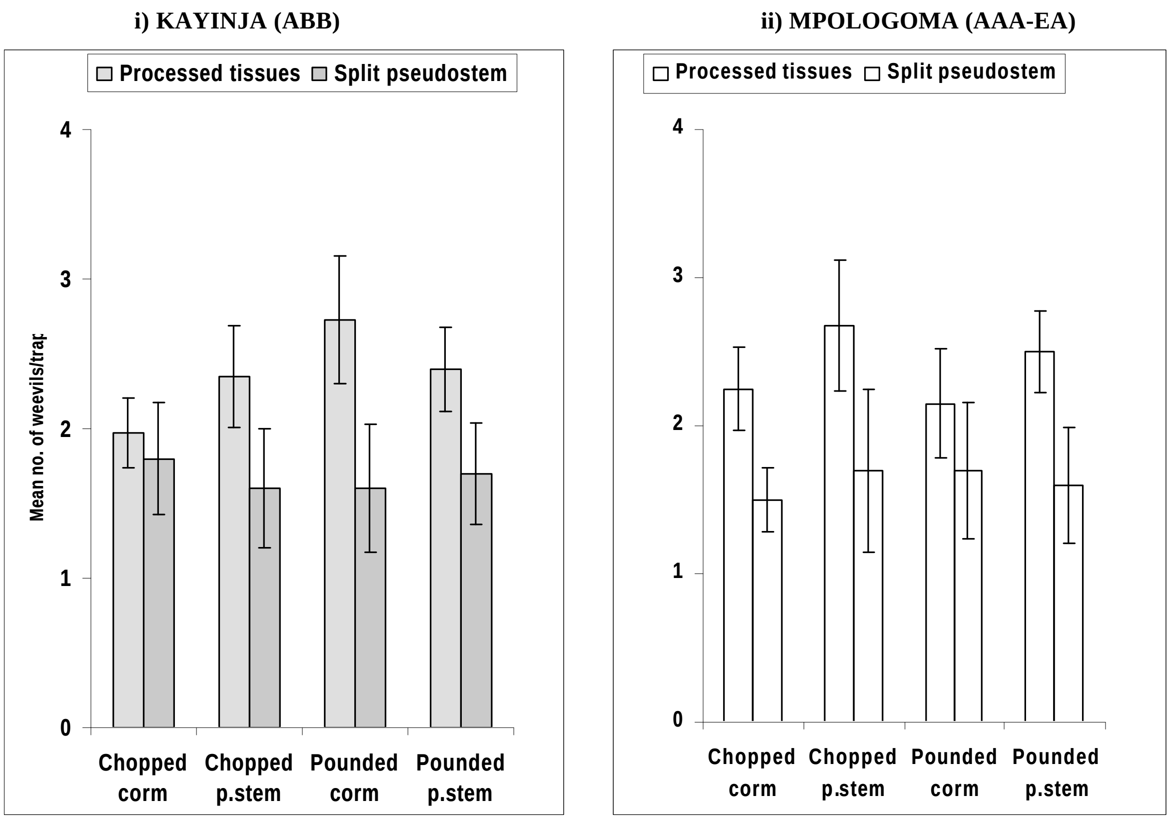

Figure 2: Average number of banana weevils captured by processed banana tissue traps placed on the soil surface, compared with conventional pseudostem trap captures

were found to move up to 18 m in the field (Godonou, 1999). The fact that adult banana weevils can be aggregated and get infected at *B. bassiana*-treated trap, and that they can move within the field and transmit the fungus to health individuals implies that semiochemical delivery system may result in total infection of the field weevil population.

Conclusion

The challenge in the evaluation of kairomone trapping as a delivery system for *B. bassiana* remains lack of a standard check against which evaluation is based. Although weevil catches may be used as a measure of appropriateness of the trap to deliver entomopathogens, it should not be considered as the sole criterion, as this indirectly measures the ability of the trap to retain the attracted weevils. Effectiveness of a trap for the delivery of *B. bassiana* should consider variables such as number of weevils that get in contact with the fungus irrespective of the time spent at the traps site, and comparative persistence of the fungus delivered with the test traps within the habitat.

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