Research Article

Effects of insecticides with different modes of action in the control of banana weevils (*Cosmopolites sordidus*) in Cameroon

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ABSTRACT

The aim of the study was to evaluate the use of insecticides with different modes of action on banana borer weevil. Insecticides with different modes of action were administered to banana weevils (*Cosmopolites sordidus*) in small containers (1 litre by volume) with perforated lids and monitored in the laboratory at room temperature and pressure. The insecticides were also applied on plantain plants (*Musa sapientum*) in a field trial following five treatments, each replicated three times arranged in a complete randomized block design. The laboratory and field results revealed that Counter® - organophosphate with active ingredient Terbuphos (Hangzhou Tianlong Biotechnology Co., Ltd, China) and Regent® - phenyl pyrazole with active ingredient fipronyl (Kalyani Industries PVT Ltd, China) were very effective (100% mortality) in the control of banana weevil. Insector® - neonicotinoid with active ingredient imidaclopride (Heydchem Limited, China) showed a moderate effect (<20%) in the control of the weevil while Bromorex® (botanical, with pepper and chilli extracts as active ingridients) proved to be a poor insecticide against this weevil. Bromorex® also showed low non-mortality effects on the weevils with a high rate of egg laid and larvae emergence (17.3±4.5 and 1.6±0.4 respectively). Insector®, Regent® and Counter® completely inhibited larvae emergence from eggs.

Key words: insecticide, efficacy, *Cosmopolites sordidus,* Banana

RESUME

Des insecticides ont été administré au charançon de la banane (*Cosmopolites sordidus*) à l'aide de petits récipients (1 litre de volume) au couvercle perforé et suivi en laboratoire à température et pression ambiante. Ces produits chimiques ont été aussi appliqué à sur des plants de bananier (varieté Batard) suivant une expérience en champ à cinq traitement répliqué à 3 niveaux suivant un design expérimental complètement randomisé en block. Les résultats en champ et laboratoire ont montré que Counter® et Regent® sont excellent (100% de mortalité) dans le control du charançon de la banane. Insector® a montré un effet modéré (<20%) dans le control du charançon alors que Bromorex® s'est montré être non efficient contre le charançon. Bromorex® a aussi montré un bas effet sur le charançon avec un taux de production d'œuf et d émergence (17.3±4.5 et 1.6±0.4 respectivement) Insector®, Regent® et Counter® ont complètement inhibé l'émergence des larves à partir des œufs.

Mots clés: insecticide, efficace, *Cosmopolites sordidus,* Bananière

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INTRODUCTION

The banana weevil *Cosmopolites sordidus* (Germar) (Coleoptera: Curculionidae) is one of the major constraints to banana production (Gold *et al.,* 2001). The weevil lays its eggs singly at the bases of the pseudostems less than 25cm above the soil in holes perforated by ovipositing females (Abera *et al.,* 2000). Egg production is low, with oviposition estimated from 1 to 3 eggs per week. After hatching, the larvae tunnel into the corm and pseudostem of the plant resulting into stunting, delayed maturation, reduced bunch sizes, snapping and sometimes, premature death. Yield loss due to this has been reported to be up to 100% on farmer's fields while yield loss of up to 50% has been reported in on-station trials (Rukazambuga, 1998).

Many techniques (biological, cultural practices, pheromone traps, genetic manipulation and chemical control with insecticides) have been used in attempt to solve this problem, but chemical control with insecticides remains the most common and widely used method, especially in agro-plantations and some smallholder farms. Though the use of these insecticides in banana agroecosystems is indispensable and in continuous use, there are no scientific data to show efficacies and effects of these insecticides on the target pest in banana agro-ecosystems in Cameroon. Also, different plantations use different groups of insecticides and so there was a need to evaluate the effectiveness of insecticides on this pest. The aim of this study was to evaluate the efficiency of various insecticides with different modes of action in controlling the banana borer weevil.

MATERIALS AND METHODS

Study area

This research was carried out in Centre Africain de Recherches sur Bananier et Plantains (CARBAP) Njombe created by an Inter-Governmental agreement in 2001 (Okolle *et al.*, 2009). It is located in Penja Sub-Division, in the Moungo Division of the Littoral Region of Cameroon along the Douala-Nkongsamba highway road. Njombe is located between latitudes 4^0 38' 11" and 4^0 50' 92"N and longitudes 9^0 40' 55" and 9^0 56' 81"E. The area has sedimentary and volcanic fertile soils good for banana production (Sama-lang, 2004). The climate is equatorial with temperature range from 18.5^{o}C to 29^{o}C, a rainy season running from March -November, with July to October being the wettest months. The annual rainfall is about 2086 mm, mean annual temperature stands at 27.1^{o}C and relative humidity is 72% (Sama-lang, 2004).

Weevil collection and rearing

Weevils were obtained using pseudostem traps (Mitchell, 1978; Tinzaara *et al.,* 2008) and corm traps in a section of CARBAP's farm and farmer's farm, and separated into males and females. The identified females of both stocks were later given a red mark each on the back using red nail polish and the weevils air dried under room temperature for the mark to stick well on the weevils.

Laboratory studies to determine the effect of insecticides and the resistance level of weevils

The laboratory experiment comprised of five treatments in three replicates. The treatments were as follows: i)Treatment one (T1) consisted of Tap water (control), ii)Treatment two (T2) consisted of a botanical insecticide called Bromorex® with active ingredient pepper and chilli extracts whose mode of action is contact and locally systemic with a concentration of 100ml/1L of water, iii)Treatment three (T3) consisted of a neonicotynoid called Insector® 35SC with active ingredient imidaclopride whose mode of action is systemic and a concentration of 5 ml/1L of water, iv)Treatment four (T4) consisted of a phenylpyrazole called Regent® 50SC with active ingredient fipronil with mode of action purely systemic and a concentration of 5ml/1L of water and v)Treatment five (T5) consisted of an organophosphate called Counter® granules with active ingredient terbufos, with mode of action contact and locally systemic, of dose 0.5 grams per corm.

Fifteen plastic containers of one litre volume were used. In each container was put 10 weevils (5 marked males and 5 marked females) taken from the stock of weevils collected from a banana plantation farm. Fifteen small plantain corms of same size and variety (Batard variety) were prepared and put into the containers (one per container) to serve as food for the weevils. The set-up was then allowed for 24 hours to give enough time for the weevils to feed and copulate before treatment the following day. During treatment, three corms were dipped into tap water for 2-3 minutes, after which they were placed individually into three containers for treatment one. The corms for treatment two (T2) were dipped into Bromorex® for 2-3 minutes, after which they were placed into three containers one per container. The same process was repeated for treatments three (T3) and four (T4) using the respective insecticides. For treatment five, each corm was treated with 0.5 gram of the insecticide (Counter® granules). The containers were covered with perforated lids and the set-up kept in the laboratory at mean temperature of 26.9±0.18 °C and mean relative humidity 76.6±1.03%. Observations were made daily for: - the number of dead weevils of the different sexes, the number of eggs found on the surface of corms and the number of weevils of the different sexes moving away from the corms. After fifteen days of observation, corms of each treatment were carefully dissected and the numbers of living and dead larvae were counted and the damage on each corm recorded.

Field studies to evaluate the effect of the various insecticides on weevils in the field

The experiment followed a randomized block design. A piece plot in CARBAP about 20m by 12m was allocated for the trial. The plot was cleared and then divided into three blocks, and each block was sub- divided into five sub-blocks to make 15 sub-blocks. In each sub-block was planted 4 plantain plants of the 'Batard' variety, to give twenty plants for each block and a total of 60 plants for the entire experiment. Four days later, the plot was sampled for weevils and more weevils released into the plot around the plants, 10 weevils (5males and 5females) per plant.

A week later, the various insecticides were used to spray the plants using a calibrated knapsack sprayer. This trial followed the same experimental design as the laboratory study. T1 plants each received 25ml of water, T2 plants each received 100ml Bromorex®, T3 plants each received 25ml Insector®, T4 plants each received 25ml of Regent® and T5 plants were each treated with 30 grams of Counter® granules. One week after spraying, a pseudostem trap was set up in each sub-block. The traps were observed weekly and number of adult weevils caught in each sub-block was recorded weekly for three months. At the end, all plants from each sub-block were carefully uprooted and corms pared and examined for weevil infestation and damage.

Statistical analyses

For mortality of adult weevils, efficacies of the insecticides were obtained using Henderson-Tilton's formula. Data on oviposition, repulsion and presence of larvae of weevils were checked for normality and homogeneity using the method of Fowler *et al.* (1998). Log transformed data was subjected to one way ANOVA and then to Tukey's test for equal means separation.

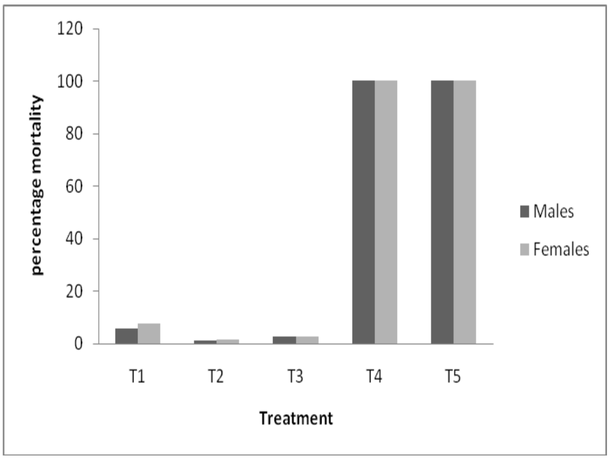
Henderson-Tilton's formula for efficacy (%) = [1-(Nta/Nca)(Ncb/Ntb)] where,

N=number of living pests per plot, t=treated plots, c=control plots, a=after treatment and b=before treatment. The methods of Vilardebo (1973) and Researchers working on weevil problems in Africa (Sadik *et al.,* 2010) were used to quantify weevil infestation.

RESULTS

The efficacies of insecticides on weevils

Treatments four (Regent®) and five (Counter®) showed 100% efficacies on the weevils after 8 days exposure in the laboratory, and this effect was same on both sexes (Figure 1). Treatment three which had Insector® with imidacloprid as the active ingredient showed low efficacy (less than 20%) on both male and female weevils.



T1= Control, T2= Bromorex®, T3=Insector®, T4= Regent®, T5= Counter®

Figure 1:Effect of insecticides on weevils after 8 days exposure

Mortality of male and female weevils

Table 1 shows the cumulative mortality rate for male and female weevils of each treatment during the eight days of the exposure. The mortality rates in the different treatments for male weevils were significantly different (P=0.0002) while Turkey's test showed that the following treatments were significantly different (P<0.05): T1 and T4, T1and T5, T2 and T4, T2 and T5, T3 and T4 as well as T3 and T5. Also, the mortality rates in the different treatments for female weevils were significantly different while Turkey's test showed that the following treatments were significantly different (P<0.05): T1 and T4, T1 and T5, T2 and T4, T2 and T5, T3 and T4, as well as T3 and T5. Mortality caused by the exposure of these weevils to the different insecticides in the laboratory showed that males had slightly more resistance to the insecticides than the females and this trend was recorded in all the different treatments. These results revealed that T4 and T5 were significantly more effective in controlling weevils on banana than T2 and T3. Highest mortality for weevils was from T5 and T4 (Table 1).

Table 1: Cumulative percentage mortality (Mean±SE) of insecticides on male and female banana weevils

Treatment	Cumulative mortality of weevils			
	Male weevils		Female weevils	
	Number	Significance level	Number	Significance level
T1	5.8±2.1	P=0.0002	7.5±0.6	P=0.003
T2	1.0±0		1.5±0.5	
T3	2.7±0.9		2.5±0.8	
T4	74.3±17.3		74.3±19.5	
T5	74.4±17.1		74.5±20.5	

T1=Control, T2= Bromorex®, T3=Insector®, T4= Regent®, T5= Counter®.

Non-mortality effects of the insecticides (oviposition, repulsion and number of larvae in corms).

Number of eggs laid and larvae emergence on corm surfaces over 15 days

From Table 2, ANOVA showed that the cumulative mean of eggs laid for the different treatments was unequal (P=0.0005). Turkey's test showed that with exception of T1 and T4 that were not significantly different (P>0.05), all the others were significantly different (P<0.05). Treatment two had the highest number of eggs while T3 had the lowest. This means that T2 was least effective in deterring egg laying by weevils while T3 was the best in deterring egg laying. There was no significant difference in the mean of larvae emergence when the treatment groups were compared. No larvae were found on banana corms in T3, T4 and T5 while larvae were found in T2 and the control T1 (Table 2). T3, T4 and T5 completely stopped larvae emergence from eggs laid on banana corms.

Table 2: Number of eggs laid and number of larvae found in corms after treatment with insecticides

Treatment	Number of egg laid		Number of larvae emergence	
	Mean±SE	Significant level	Mean±SE	Significant level
T1	7.5±2.7	P=0.0005	2.3±0.6	P=0.09
T2	17.3±4.5		1.6±0.4	
T3	3.7±0.9		0.0±0	
T4	7.4±1.9		0.0±0	
T5	5.1±1.3		0.0±0	

T1=Control, T2= Bromorex®, T3=Insector®, T4= Regent®, T5= Counter®

Repellent activity of selected insecticides

From Table 3, the percentages of male weevils repelled daily after the application of the different treatments were unequal (P=0.000). Turkey's test showed that only T1 and T2 and T4 and T5 were not significantly different (P>0.05). Similarly, the percentages of female weevils repelled after the application of the different treatments were unequal (P=0.000). The following treatments were significantly different (P<0.05): T1 and T3, T1 and T4, T1 and T5, T2 and T3, T2 and T4, as well as T3 and T5. The results revealed that repulsion of weevils by the different insecticides did not depend on the sex of the weevil except in treatment three (T3) where there was a greater number of repelled female weevils than male weevils.

Table 3: Percentage of weevils (Mean±SE) repelled in the different treatments

Treatment	No. of Repelled weevils			
	Males		Females	
	Mean±SE	Level of significance	Mean±SE	Level of significance
T1	11±4.4	P=0.000	12.4±4.7	P=0.000
T2	4.8±1.8		6.7±2.5	
T3	63.8±24.5		71.4±27.4	
T4	88.6±22.7		88.6±22.7	
T5	97.1±37.3		95.2±12.6	

T1=Control, T2= Bromorex®, T3=Insector®, T4=Regent®, T5= Counter®.

External corm damage (CI) and internal corm damage (PCI) of plants from the field

From Table 4, it was observed that the means for CI were not significantly different (P =0.4913). Also, ANOVA showed that the sample means for PCI were not significantly different (P =0.5805). The external corm damage (CI) results showed that T3 was the most effective in the field trial in the control of banana weevil, followed by T4 and then T2. T5 was the least effective. For external corm damage (PCI), results showed that T4 was the most effective in the field trial, followed by T3 and then T2. Again T5 was the least effective.

Table 4: External and internal corm damage by weevils after 12 weeks period in the field following treatment with insecticide.

Treatment	Internal corm damage (CI)	Level of significance	External corm damage (PCI)	Level of significance
T1	5.8±1.7	P=0.4913	15.5±4.5	P=0.5805
T2	2.9±0.8		5.1±0.2	
T3	1.3±0.4		4±1.2	
T4	2.5±0.7		3±0.8	
T5	3.3±0.9		8±1.9	

T1=Control, T2= Bromorex®, T3=Insector®, T4= Regent®, T5= Counter®.

DISCUSSION

Results of efficacies on effects of insecticides showed that T5 (Counter® granule) was the most effective in control of banana borer adults, followed by T4, then T3 and T2. Mortality caused by exposure of these weevils to the insecticides showed that females died faster than males indicating that males were more resistant than females. Insector® (T3) efficacy for adult weevils was lower than reported by Okolle *et al.* (2009) who indicated that Insector® was excellent in the control of black weevils. The results also indicated that T5 (Counter® granule) was an excellent insecticide in adult weevil control, which agrees with the report by Chavarria-Carvajal and Irizarry (1997), Chabrier *et al.* (2002) and Fogain *et al.* (2002). Okolle *et al.* (2009), however, reported that Counter® had only a moderate effect in the control of this weevil. Regent® (T4) also produced an excellent result, which agrees with the report of Okolle *et al.* (2009) on weevil control in Cameroon. There have been reports of resistance against Regent® 5G and Counter® in the control of banana weevils (Smith 1995). However, this trial showed that weevils in Cameroon have not yet developed resistance to Insector®, Regent® 50SC and Counter®. As for Bromorex®, results revealed that it was not a good insecticide in the control of banana weevils and this corroborates the report of Okolle and Mankah (2010). Tinzaara *et al.* (2006) reported that most plant extracts that have insecticidal properties do not have direct toxicity but can control pests through affecting biological activities which agrees with the results obtained in this trial. For non-mortality effects of insecticides on banana weevils, Bromorex® showed the least effect in inhibiting egg laying and number of larvae found in banana corms, which is contrary to the reports of Isman (2006), Okolle and Mankah (2010) that pepper extract inhibits egg laying and hatching. These differences may be differences in concentration of the chemical that was used. Repulsion of weevils was seen not to depend on the sex of the weevils in this study except in Insector® where there was an increase in the number of repelled female over male weevils. Treatment five (Counter®) recorded the best results for repulsion of weevils. The repulsive effect might have resulted from the very sharp offensive odour of Counter® insecticide.

In the field, Insector® and Regent® prevented weevil damage the most, showing that they are good systemic insecticides. This means that during feeding by the weevils, the chemicals are ingested and the weevils die in the course of penetrating into the banana corms, hence the low damage observed . Bromorex® and Counter® showed the highest damage, implying that the insecticides proved to be the least effective in terms of preventing damage; hence they are more of contact insecticides. These results, however, do not follow the trends recorded in the laboratory exposure of the weevils to the various insecticides, as well as the results obtained from the density (occurrence) of the weevils in the field where Regent® and Counter® proved to be the best in laboratory studies. Treatment five (Counter®) killed weevils (adult) but it was possible that in spite of the high mortality, some weevils still had the chance to lay eggs on or in the corms. Once larvae ensued inside the corm, Counter® (T5) had no powers to kill them since it was contact insecticide and could not penetrate into the corms.

From the results obtained in the study, it may be concluded that effective control of banana weevils in Cameroon can be achieved by the use of insecticides Counter® (T5) and Regent® (T4). The mortality effects of insecticides on weevils varied with sex of weevils, with males proving more resistant than females. Insecticides had non-mortality effects on banana weevils (egg laying, larvae emergence and weevil repulsion).

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