International Journal of Tropical Insect Science Vol. 25, No. 1, pp. 19–24, 2005 DOI: 10.1079/IJT200548

Effects of covering highland banana stumps with soil on banana weevil *Cosmopolites sordidus* (Coleoptera: Curculionidae) oviposition

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(Accepted 3 December 2004)

Abstract. The effect of covering post-harvest banana stumps with soil on banana weevil *Cosmopolites sordidus* (Germar) oviposition levels was investigated at three locations, Sendusu, Kawanda Agricultural Research Institute (KARI) and Ntungamo district of southwestern Uganda. In the first experiment oviposition levels were assessed in a banana system comprising growing plants and residues. Oviposition increased on sword suckers, reaching a peak 1–7 days after harvest and decreased thereafter. In the second experiment conducted on farmers' fields, corms received 70% of the eggs and pseudostems 30%. The area 5–10 cm below the collar received 27% of the eggs, the area 0–5 cm above the collar 30% and the area 5–10 cm above the collar 0.3%. The remaining eggs (43%) were laid 0–5 cm below the collar. The effect of stump height and covering the stumps was evaluated in both the wet and the dry seasons at Kawanda and Ntungamo. Cutting stumps to the ground level alone had no effect on oviposition. Covering post-harvest banana stumps reduced *C. sordidus* oviposition in the wet but not in the dry season.

Key words: banana, banana weevil, *Cosmopolites sordidus*, crop sanitation, cultural control

Résumé. L'influence du recouvrement avec de la terre, après récolte, des souches de bananiers sur les taux d'oviposition du charançon du bananier *Cosmopolites sordidus* (Germar) a été étudiée dans trois localités, Sendusu, la station de recherche agricole de Kawanda (KAR1) et dans le district de Ntungamo au sud Ouest de l'Ouganda. Dans la première expérience nous avons évalué les taux d'oviposition dans un système cultural associant des plantes sur pied et des résidus. L'oviposition augmente sur les rejets pour atteindre un pic 1 semaine après la récolte puis décroît ensuite. Dans la seconde expérience conduite dans des parcelles paysannes, les bulbes reçoivent 70% des œufs et les rejets 30%. La zone située entre 5 et 10 cm sous le collet reçoit 27% des œufs, celle située entre 0 et 5 cm au dessus 30% et celle située entre 5 et 10 cm au dessus 0,3%. Les œufs restants (43%) ont été déposés entre 0 et 5 cm sous le collet. L'influence de la hauteur de son recouvrement a été évaluée aussi bien pendant les saisons des pluies que les saisons sèches à Kawanda et Ntungamo. Si on rabaisse la souche au niveau du sol cela n'a aucune incidence sur l'oviposition. Le recouvrement des souches après récolte limite l'oviposition du charançon en saison des pluies mais pas pendant la saison sèche.

Mots clés: banane, charançon du bananier, *Cosmopolites sordidus*, contrôle sanitaire, contrôle cultural

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Introduction

Highland cooking banana (*Musa* spp., genome group AAA-EA) is a primary food and a cash crop in the Great Lakes region of eastern Africa (INIBAP, 1986; Gold *et al.*, 1999a). It is grown mainly by resource-poor farmers on smallholdings with low levels of inputs. The banana weevil *Cosmopolites sordidus* (Germar) (Coleoptera: Curculionidae) is a primary production constraint of highland banana in the region and has been an important cause for the crop's decline and disappearance in central Uganda (Gold *et al.*, 1999a). The larval tunnel in the corm impedes water and nutrient uptake and weakens the stability of the mat. *Cosmopolites sordidus* attack can result in delayed maturation, snapping, toppling, reduced bunch weight, mat die-out and shortened plantation life (Rukazambuga *et al.*, 1998; Gold *et al.*, 2001).

The biology of *C. sordidus* has been reviewed by Gold *et al.* (2001). It is a K-selected insect with a long lifespan (up to 4 years) and a low fecundity (<2 eggs/week). The adults are free living, crawl only short distances, rarely fly and are most often found at the base of the banana mat or associated with the cut residues. They are attracted to their host by plant volatiles (Budenberg *et al.*, 1993). They are hygrotrophic and most active in the rainy season or in mulched rather than bare banana fields. *Cosmopolites sordidus* attacks only plants of the related genera Musa and Ensete.

After harvest, crop residues serve as shelters for adults (Gold *et al.*, 1999b). Abera (1997) found 25–32% of *C. sordidus* eggs on cut residues and 10–12% on standing stumps, while Masanza *et al.* (2004) found oviposition and larval development on residues up to 120 days after harvest. Abera (1997) found most oviposition to be in the leaf sheaths at the base of the pseudostem. However, banana corms are generally considered more attractive to adults than pseudostems and very often more oviposition is observed in the corms (Gold *et al.*, 2001; Masanza *et al.*, 2004). In some resistant clones, infestation may reach high levels in crop residues, thereby increasing populations that can attack susceptible plants (Gold and Bagabe, 1997).

Crop sanitation (i.e. destruction of crop residues) has been widely recommended as an important control strategy for *C. sordidus* (Ghesquiere, 1925; Seshu Reddy *et al.*, 1998; Gold *et al.*, 2001). Farmers practise a wide range of sanitation activities which include cutting the stem at ground levels, covering the corm with soil, removing the corm, subsequent cutting of the pseudostem and the corm into small pieces and stripping the leaf sheaths. Although farmers often recognize that residue corms serve as hosts for *C. sordidus* larvae, they show reluctance in removing them because of the labour involved and the fear of destabilizing the mat. Therefore, a number of farmers cover harvested corms with soil with a belief that this might prevent infestations of *C. sordidus*. However, no data are available to show such a method is effective in protecting the corms against ovipositing weevils.

The objectives of this study are: (i) to determine the distribution of *C. sordidus* eggs on banana stumps; and (ii) to evaluate the effect of covering corms with soil on *C. sordidus* oviposition.

Materials and methods

The research was conducted at the International Institute of Tropical Agriculture's Sendusu Farm, the Kawanda Agricultural Research Institute and on farmers' fields in Ntungamo district of southwestern Uganda. Sendusu is 28 km northeast of Kampala (0°32′N, 32°32′E), 1260 m asl and Kawanda is 13 km north of Kampala (0°25′N, 32°32′E), 1195 m asl Both sites have 12-h day-length throughout the year, mean daily temperatures between 17 °C minimum and 29 °C, mean annual rainfall of 1200 mm and two rainy seasons (March–May and September–December). Study farms in Ntungamo district (0°53′S, 30°13′E) were between 1300 and 1560 m asl with mean daily temperatures between 15 °C minimum and 28 °C mean annual rainfall at the site varying from 800 to 1500 mm with bimodal distribution (March–May and September–December).

Experiment 1: Distribution of Cosmopolites sordidus *eggs in banana stumps*

To determine the relative importance of oviposition on stumps within mats, *C. sordidus* oviposition preferences on different aged plants were determined in two six-year-old banana (cv. Atwalira, AAA-EA) plots (115 × 12.5 m) at Sendusu Farm. The original plant spacing was 2.5 × 2.5 m, but sustained weevil attack resulted in high levels of mat die-out. At the time of sampling, 40–50 mats remained per plot. The data collected in this experiment complemented earlier distribution studies in the same site reported by Masanza *et al.* (2004).

A total of seven plant or residue stages were sampled from each of the 11 mats. Each mat consisted of one sword sucker, one maiden sucker, one pre-flowered plant and one flowered plant. Where possible, residues of three different aged classes (<7 days after harvest (DAH), 14–30 DAH, >30 DAH) were sampled for each mat. Otherwise, a correspondingly-aged residue was taken from a neighbouring mat.

Data collection was by destructive sampling, involving uprooting whole mats using hoes and digging spears. Each sucker or residue was pared carefully to expose the eggs that had been deposited by the resident weevils (natural infestation).

Experiment 2: Distribution of Cosmopolites sordidus *eggs across different sections of banana stumps*

To establish banana weevil oviposition preferences on different parts of banana stumps (i.e. near or distal to the collar and the soil surface), field trials were conducted in two multicultivar highland banana stands in Ntungamo district. Each stand was >50 years old and supported heavy infestations of *C. sordidus*. The fields were each 1 ha and were maintained at low-sanitation levels with different aged residues scattered throughout the farm. Most commonly, the pseudostems were cut <1 m above the ground. In all the cases, the corm of the stump was left in the soil in situ attached to the remainder of the mat.

Sampling was conducted during the rainy season of March–April 1999. Thirty banana stumps of different ages (i.e. 1–8 weeks after harvest) were randomly selected on each farm and extracted from the soil with the corms intact using a digging spear. The stumps were divided into four zones: (i) corm 0–5 cm below the collar; (ii) corm 5–10 cm below the collar; (iii) pseudostem 0–5 cm above the collar; and (iv) pseudostem 5–10 cm above the collar. Each zone was carefully pared using sharp knives to expose *C. sordidus* eggs and first instar larvae.

Experiment 3: Effect of covering banana stumps with soil on Cosmopolites sordidus *oviposition*

Experiment 3a

The effects of covering banana stumps with soil on *C. sordidus* oviposition were studied in two trials: (i) in an existing field trial at Kawanda; and (ii) on a farmer's field in Ntungamo district. Each trial consisted of three treatments: (i) banana stumps cut 5 cm above the ground level; (ii) banana stumps cut at the ground level and left exposed on the surface; and (iii) banana stumps cut 5 cm below the ground level and covered with soil. Each trial was laid out in a completely randomized design with 10 replicates. After 2 weeks, the stumps were removed from the soil with a digging spear and pared using sharp knives to expose eggs and first instar larvae. At each site the trial was repeated in the wet and the dry seasons.

Experiment 3b

The trial was conducted at KARI and consisted of two treatments in which recently harvested residues (i.e. <7 days old) were: (i) cut at the ground level and left exposed; and (ii) cut at the ground level and covered with a 5-cm-thick layer of soil. The treatments were arranged as matched pairs with 10 replicates. After 2 weeks, the stumps were removed from the soil and dissected for eggs and first instar larvae as in experiment 3a. The trial was conducted in both the wet and the dry seasons.

Data analysis

For experiment 1, the means for the number of eggs found on the suckers and on the residues were subjected to general analysis of variance using Genstat version 3.2 on a generalized linear model (GLM). The orthogonal polynomial method was employed to compare trends in oviposition among the seven treatments (assuming time was embedded in treatments). Mean separation was done using the least significant difference. For experiment 2, means of eggs were pooled and analysed as from one farm. Means for eggs at a particular location on all the residues were pooled and analysed as eggs on corm or pseudostem at different zones on these residues using general linear model (GENMOD) procedure of SAS (SAS Inst. Inc., 1997). Means were separated using least square means (LS means) probabilities. For experiment 3a, means of eggs were analysed using the ANOVA procedures of SAS (SAS Inst. Inc., 1997) and differences in treatment effects were detected by the use of mean contrasts. In experiment 3b, means of eggs were subjected to a matched pair *t*-test to detect the differences in treatment effects.

Results

Experiment 1: Distribution of Cosmopolites sordidus *eggs in banana stumps*

Cosmopolites sordidus oviposition increased with plant age, peaked on <7-day-old residues and then declined thereafter (Fig. 1). Mean oviposition on <7-day-old residues was five times higher than on sword suckers. The data best fitted a quadratic polynomial distribution ($P < 0.05$, d.f. = 60).

Experiment 2: Distribution of Cosmopolites sordidus *eggs across different sections of banana stumps*

Cosmopolites sordidus eggs were found throughout the corm and in the lower 5 cm of the pseudostem, with very little oviposition in the pseudostem >5 cm above the collar (Fig. 2). Seventy percent of the eggs were placed on the corm with about 60% of these found in the upper 5 cm. High mat (where a large part of the corm appears above the ground) was uncommon on the study farms, such that the upper 5 cm of the corm tended to correspond to the upper 5 cm of the soil.

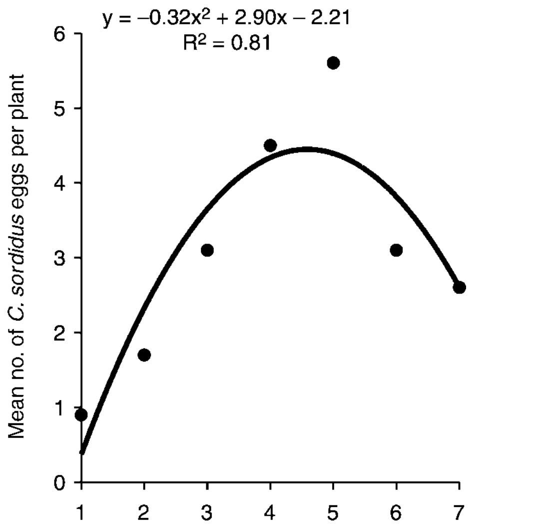

Fig. 1. Mean number of *Cosmopolites sordidus* eggs on growing plants and crop residues in a banana system at IITA's Sendusu Farm, Namulonge, Uganda. (1) sword sucker; (2) maiden sucker; (3) pre-flowered; (4) flowered; (5) post-harvest 1–7 Days after harvest (DAH); (6) 14–30 DAH; (7) >30 DAH. (quadratic polynomial fitted the data; lsd = 3.03, e.s.e = 1.07).

Experiment 3: Effect of covering banana stumps with soil on Cosmopolites sordidus *oviposition*

In experiment 3a, *C. sordidus* oviposition was four times higher during the wet season on exposed stumps than on the stumps covered by a layer of soil in both the Kawanda and the Ntungamo trials (Fig. 3). In contrast, in the dry season, stumps covered with soil to a depth of 5 cm received 59 and 73% higher oviposition than the stumps left exposed at the ground level at Kawanda and Ntungamo, respectively.

Similar seasonal trends were found in experiment 3b. Fifty percent more *C. sordidus* eggs were placed on bare stumps than covered stumps in the wet season although the difference was not significant (Fig. 4). In contrast, nearly three times more eggs were found on covered stumps than on bare stumps during the dry season ($P < 0.05$).

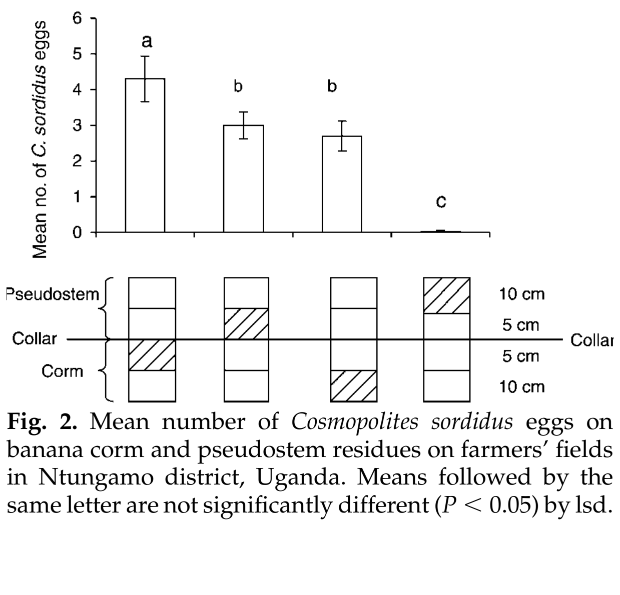

Fig. 2. Mean number of *Cosmopolites sordidus* eggs on banana corm and pseudostem residues on farmers' fields in Ntungamo district, Uganda. Means followed by the same letter are not significantly different ($P < 0.05$) by lsd.

Discussion

The results of this study indicate that the crop residues are a favoured oviposition site for *C. sordidus* in comparison with the growing plants. Fresh residues appear to be most attractive to gravid females as peak oviposition occurred on crop residues aged 1–7 days after harvest. It is likely that the cutting of the plant at harvest time results in the release of volatiles that are used in host location by the insect. In this study, the number of eggs on older residues declined, suggesting that sanitation as a weevil control measure is most critical in the weeks following harvest. It might be beneficial to use these residues as a 'trap crop' by allowing the weevils to oviposit for a week and then destroy the residues and any immatures in them.

Farmers in Ntungamo and other districts of Uganda have suggested that covering the residual stumps following harvest may reduce *C. sordidus* breeding and subsequent attack on banana plants. However, no data are available to demonstrate that such a practice, in fact, has any effect on *C. sordidus* populations.

The data in this study suggest that oviposition on the corm is more important than on the pseudostem. Seventy percent of oviposition occurred in the corm, with more eggs in the upper 5 cm than 5–10 cm below the collar. Similar results were reported by Cuille and Viladebo (1963) and Koppenhoffer (1993), while Abera (1997) found more eggs on the corm than the pseudostem only in systems with high mat (exposure of the corm above the ground surface). On bananas without high mat, Abera (1997) reported the majority of oviposition on the pseudostem although 75% of all the eggs were below the soil surface. These results suggest that the protection of the corm and the portions of the pseudostem below the ground may be most important in crop residue management.

Our results show that deep cutting of the corm and its removal may be beneficial in the wet season since *C. sordidus* adults are more likely to be active on the soil surface. Under these conditions, covering banana stumps after harvest appears to have deterred host finding and oviposition. Nevertheless, it is also possible that oviposition on banana plants might increase if all stumps were buried during the wet season.

In the dry season, oviposition was three times higher on covered stumps than on those cut at the soil surface, even though the soil cover was expected to form a physical barrier to gravid females (Karamura

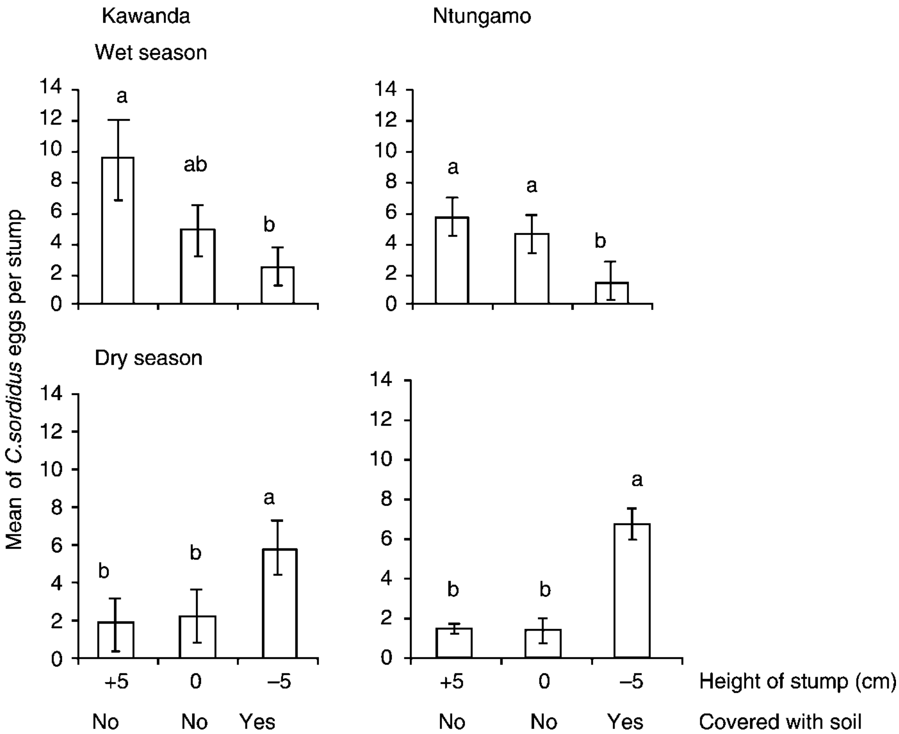

Fig. 3. Effect of banana stump height and exposure on *Cosmopolites sordidus* oviposition levels in the wet and the dry season trials at the Kawanda Agricultural Research Institute and on a farmer's field in Ntungamo district, Uganda. For each site within season, means of eggs followed by the same letter are not significantly different ($P < 0.05$) by pair-wise comparison *t*-test of least square means.

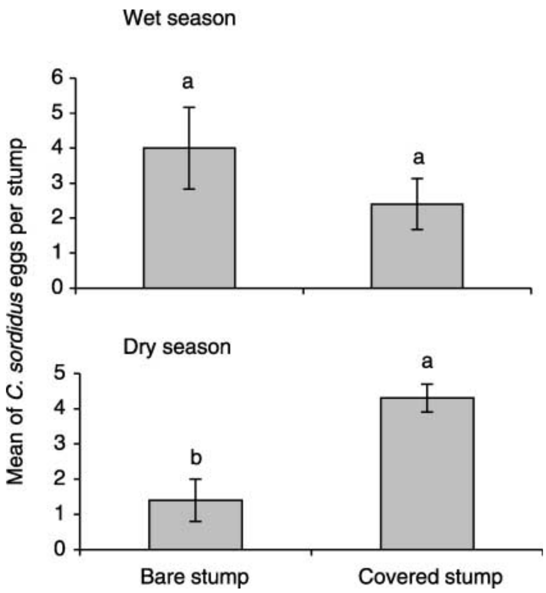

Fig. 4. Effect of covering banana stumps cut below the ground level with a 5-cm-layer of soil on *Cosmopolites sordidus* oviposition in the wet and the dry seasons at Kawanda. Means followed by the same letter are not significantly different ($P < 0.05$) by pair-wise comparison *t*-test of least square means.

and Gold, 2000). *Cosmopolites sordidus* adults are positively hydrotropic, search for the highest air humidity and liquid water and are unsettled in environments with low humidity (Cuille, 1950; Roth and Willis, 1963; Ittyeipe, 1986). This suggests that the females may only oviposit under conditions of favourable soil moisture, which did not exist at the soil surface during that period. It is also likely that covering of banana stumps in the dry season preserves plant moisture, which probably also encourages *C. sordidus* oviposition. If left bare, the corms dry up quickly, making them not suitable for weevils. Therefore, farmers might be advised to cut their harvested banana stumps 5 cm below the soil in the wet season only and that they should not cut and cover these stumps during the dry season. Residues should probably be left in the field one week after harvest, allowing *C. sordidus* time to oviposit before the residues are subsequently destroyed. This will help in reducing attack on standing plants.

Acknowledgements

The Rockefeller Foundation provided financial support for this study through a fellowship administered by IITA. The cooperation of farmers in Ntungamo, allowing us to work on their farms is gratefully appreciated. Mr Philip Ragama advised on data analysis, while John Bosco Ssentongo assisted in data collection.

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