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Use of crop sanitation for the management of the banana weevil in Uganda

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Abstract

Removal and destruction of banana crop residues after harvest has been widely recommended for the control of banana weevil, *Cosmopolites sordidus* control. However, there is scanty information of the actual effect of this practice on the banana weevil populations and damage. This study aimed at investigating the effect of crop sanitation on the population dynamics of this pest and its associated damage. Laboratory and field studies were conducted in Uganda to study the biology and ecology of this pest on crop residues. We found that corms are the most attractive of all residues parts. Fresh residues were most attractive but oviposition occurred on residues up to 120 days after harvest. An on-farm study of the effect of crop sanitation on populations and corm damage was conducted through farmer participatory trials in Ntungamo district, Uganda. Increase in sanitation level from low to high significantly reduced banana weevil adult populations, lowered corm damage, increased plant maturation rates and increased yields. The data suggest that improved sanitation management can contribute to *C. sordidus* control and improved banana productivity.

Key words: Banana*Cosmopolites sordidus*, crop residues, yields

Introduction

The banana weevil, *Cosmopolites sordidus* (Germar) (Coleoptera:Curculionidae) is an important pest of East African highland banana in Uganda. It has been a primary contributing factor to the decline and disappearance of highland banana in the country's central zone during the last 30 years (Gold et al. 1999a). The larvae bore in the corm, weakening the stability of the mat and impeding nutrient uptake. Banana weevil attack can result in plant loss (through toppling and snapping), reduced bunch weights, mat disappearance and shortened plantation life (Gold *et al.* 2001). In on-station trials, Rukazambuga et al. (1998) and Gold *et al.*, 2004 estimated yield losses attributable to banana weevil at > 40 to 60% in ratoon cycles, while Sengooba (1986) observed total crop failure on banana plantations during banana weevil outbreaks in the country's southwest.

The adults are free living and most often found at the base of the banana plant or proximal to crop residues. Stand management, especially crop sanitation practices, can influence the distribution of adults. Treverrow and Bedding (1993) found crop residues to host 60% of adult weevils in one stand, while Gold et al. (1999b) found 25-32% of adults in prostrate residues and another 10-12% in standing stumps. Adults may live up to four years but produce few eggs per week (Gold *et al.*, 2001). Eggs are placed in the base of the plant. Under field conditions, Abera *et al.* (1999) reported 33% of banana weevil oviposition to be in standing crop residues (i.e. still attached to the mat). The larvae tunnel in the corms of growing plants and residues. Pupation is within the corm.

In Ecuador, banana weevils preferably attacked Gros Michel (AAA) residues (Vilardebo, 1960). In Uganda, Gold and Bagabe (1997) found little infestation on recently harvested plants of the resistant cultivar Kisubi (AB), but observed increasing attack over time following harvest. Infestation levels were higher on cut and prostrate residues than on standing stumps. Similarly, in Indonesia, Gold and Hasyim (unpubl. data) found no larvae in recently harvested Pisang Awak plants (ABB), but more than 100 on a single cut and prostrate residue. These data suggest that banana weevils are attracted to, oviposit on and develop within crop residues. As a result, crop sanitation (i.e., destruction of residues) has been recommended as a means of weevil control in Uganda.

It is widely believed that destruction of crop residues (splitting of harvested pseudostems and/or removal of corms) eliminates adult refuges, food sources and breeding sites, lowers overall banana weevil populations and reduces damage on standing plants in susceptible clones (Gold *et al.*, 2001). Residues may also serve as traps that draw gravid females away from growing bananas (Waterhouse and Norris, 1987). Crop sanitation as a means of banana weevil control has been recommended since the 1920s (Froggatt, 1924) and continues to be widely recommended (Seshu

Reddy *et al*., 1998). Nevertheless, few data are available to demonstrate the effects of crop sanitation on banana weevil populations and damage.

The primary objectives of this study were: (1) to determine banana weevil preference, performance and distribution on different types of crop residues; and (2) to evaluate different types of residue management practices on banana weevil populations and damage under field conditions.

Materials and methods

The research was undertaken in laboratory experiments and a field trial at the Kawanda Agricultural Research Station (KARI) and on farmers' fields in Ntungamo sub-county, Ntungamo district, Uganda. KARI (0°25'N, 32°32'E, 1190 m above sea level) is 13 km north of Kampala, with mean annual precipitation of 1190 mm, and average daily temperatures of 16 °C minimum and 29 °C maximum. The Ntungamo site (0° 52.88'' to 0° 53.79'' S; 30° 13.66'' to 30° 13.85'' E; 1300 to 1560 masl) mean annual rainfall ranged from 800 to 1500 mm and average temperatures of 15 °C minimum and 28 °C maximum.

Banana weevil preference, performance and distribution on different types of crop residues

Female attraction to and acceptance of different aged residues

Corm or pseudostem pieces were cut from different aged-field collected residues and presented to groups of 70 adult banana weevils (35 of each sex) in plastic containers (50 cm diameter, 20 cm high). The treatments were (1) fresh maiden sucker corm; (2) fresh corm (< 2 days after harvest = DAH); (3) old corm (14-30 DAH) (4) very old corm (>30 DAH); (5) fresh pseudostem (< 2 DAH) (6) old pseudostem (14-30 DAH) and (7) very old pseudostem (>30 DAH). In each bioassay, banana pieces (one per treatment) were placed equidistant from each other and the centre of the basin, using a completely randomised design. The experiment was repeated 10 times. After 24 hours, the number of male and female banana weevils aggregating around each banana piece was counted.

Banana weevil distribution on different types of residues under field conditions

This experiment was conducted on two multi-cultivar highland banana stands (> 50 yr old) with high banana weevil populations in Ntungamo sub-county. Each field was 1 ha and maintained at a low sanitation level. Residues were either left *in situ* on the mat or cut and left lying in the field. These residues were grouped into five age class treatments: (1): 0-7 DAH; (2) 8-14 DAH; (3) 15-30 DAH; (4) 31-60 DAH; and (5) 61-120 DAH. A total of 468 residues were carefully examined for banana weevil adults and immatures using methods described by Masanza (2003).

Eclosion success on different aged corm residues

The effects of residue age and state of decomposition (cv Kisansa) on eclosion success of banana weevil eggs was determined for four different corm age classes: (1) fresh (1-2 days after harvest); (2) moderately-old (14-30 days); (3) old (31-60 days); and (4) very old (= advanced decomposition) (> 90 days). Corm pieces (7 x 3 x 1 cm) were excised from field-collected residues of different ages. Ten eggs (< 24 hr old) were inserted into small notches cut into each corm piece. The corm pieces were dissected 10 days later and the fates of the eggs were determined. The experiment was replicated 20 times.

Influence of residue age on larval survivorship

Larval survivorship was determined on corms for three residue age classes: (1) fresh corm (1-2 DAH); (2) intermediate-aged corm (7-14 DAH); and (3) very old corm (60-90 DAH). First instar larvae (< 24 hour old) were obtained from banana weevil colonies maintained in the laboratory and inserted into slits made in split corm pieces (7 x 3 x 1 cm) for the different treatments (see Masanza 2003). The larvae were monitored every three days until pupation, with corm material changed at similar intervals. The experiment (50 larvae per treatment) was repeated four times.

Evaluation of covering highland banana stumps with soil on banana weevil oviposition.

This experiment consisted of three treatments: 1) banana stumps cut 5 cm above ground level; 2) banana stumps cut at ground level and left exposed on the surface; and 3) banana stumps cut 5 cm below ground level and covered with soil. The stumps were removed from the field 14 DAH and dissected for eggs and larvae. The experiment was conducted during both the wet and dry season in both KARI and in Ntungamo sub-county. For each trial, there were 10 replicates per treatments.

Evaluation of crop residue management on banana weevil populations and damage in farmers' fields in Ntungamo sub-county.

A baseline survey was first conducted on 60 farms to characterize sanitation levels (see Masanza 2003) and to estimate banana weevil populations and damage using the methods of Gold *et al.* (1994) and Gold and Bagabe (1997). Seventy-five percent of farmers practiced low, 20% moderate and 5% high levels of sanitation. Groups of farmers were asked to increase their sanitation level (i.e. from low to medium; from low to high; and from medium to high). Banana weevil populations and damage were made over a period of 3 years. Some farmers were erratic in their implementation of treatments. Therefore analysis was conducted using an incomplete cyclic design.

Results

Female attraction to and acceptance of different aged banana residues.

Twenty-four hours after release, 95% of banana weevil adults were found in contact with banana materials. Maiden sucker corm, fairly old corm (14-30 DAH) and very old corm residues (> 30 DAH) were most attractive to banana weevils, while fresh corm was least attractive (Figure 1). Age had no effect on attractivity of pseudostem residues.

There was significantly higher oviposition on corms than on pseudostems ($P < 0.01$) (Table 1a). The greatest amount of oviposition occurred on corms from maiden suckers and old (14-30 DAH) residues. Oviposition on pseudostem residues was low and similar on all aged residues. Individual females placed more eggs on corms of maiden suckers and fresh (1-2 DAH) residues than on other materials (Table 1b).

Banana weevil distribution on different types of residues under field conditions.

During the sampling period, oviposition levels were low in spite of the relatively high banana weevil infestation levels that were present in the experimental fields (Table 2). Females accepted for oviposition all stages of crop residues including those up to 120 days after harvest. Residue age had little effect on numbers of larvae, pupae and teneral adults. Oviposition levels were also similar (1) on standing and prostrate residues and (2) on residue corms and pseudostems (Table 3).

Eclosion success on different aged corm residues

Eclosion rates on fresh (66 $\pm$ 3%), moderately old (67 $\pm$ 4%) and old corms (64 $\pm$ 4%) were not significantly different from each other ($p > 0.05$). These three treatments all had significantly higher eclosion rates than those on very old corms (58 $\pm$ 4%) ($p < 0.05$).

Influence of residue age on larval survivorship

Allometric curves showed that banana weevil larval mortality was lowest on sword suckers (B = -0.75, R^2 = 0.98) and fresh corm (B = -0.75, R^2 = 0.92), while the highest mortality (B = -1.08, R^2 = 0.99) was recorded on very old corms. Larval stage duration and date of adult emergence (i.e. combined larval and pupal periods) increased with residue age (Table 4). In addition, fewer individuals successfully pupated on older plants and residues.

Evaluation of covering highland banana stumps with soil on banana weevil oviposition

Banana weevil oviposition was four times higher during the wet season on exposed stumps than on stumps covered by a layer of soil in both the Kawanda and Ntungamo trials (Figure 2). Fifty percent more banana weevil eggs were placed on bare stumps than covered stumps in the wet season although the difference was not significant. In contrast, nearly 3 times more eggs were found on covered stumps than on bare stumps during the dry season ($p < 0.05$).

Evaluation of crop residue management on banana weevil populations and damage in farmers' fields in Ntungamo sub-county

Baseline banana weevil population densities were similar for farms that practiced different levels of sanitation ($p > 0.05$) (Figure 3). Population density did not significantly differ ($p > 0.05$) on banana stands maintained at low, moderate and high sanitation until June 2001, or 26 months after the baseline data were taken. At that point, population densities significantly increased above the baseline for stands maintained at low sanitation: i.e. from 3,000 in March 1999 to 52,000 in June 2001, while there was a much more moderate increase for farms maintained at moderate sanitation levels (i.e. 4,000 in March 1999 to 13,122 in June 2001). Population density on farms maintained at high sanitation levels did not significantly change ($p > 0.05$) from baseline levels throughout the study period, and was significantly ($p \leq 0.05$) lower than the densities found at other sanitation levels.

Among farms with low initial sanitation levels, baseline population densities were also similar ($p > 0.05$) for groups of farms that were then assigned to different sanitation levels (i.e. treatments) (Figure 4). No significant differences were found among treatments until June 2001 (23 months after initiation of the study), at which point, population densities on farms upgraded from low to moderate and from low to high were significantly ($p \leq 0.05$) lower than that on farms maintained at low sanitation. However, on the two subsequent sampling dates trends were not clear.

In 2002, total damage for farms with high sanitation throughout was 1.5%, while damage in farms that maintained low sanitation averaged 3.6% (Table 5). On farms with initially low levels of sanitation, increasing sanitation levels resulted in lower levels of banana weevil damage. Total damage decreased by 41% on farms upgraded from low to high sanitation, and 43% for those upgraded from moderate to high sanitation. This was most clearly reflected in changes in damage to the central cylinder (decreases of 65% and 76%, respectively). In contrast, total damage remained at the same levels on farms that maintained low levels of sanitation throughout the study. On farms maintained at moderate and high sanitation levels, total damage decreased by 23% and 35%, respectively, during the study.

Sanitation level affected plant growth rates linearly. In August and November 2000, plants were shortest in the three treatments derived from farms with initially low sanitation levels (Table 6). Yields were affected by sanitation level. Farms employing high levels of crop sanitation had the highest bunch weights (> 20 kg) although these were not significantly different than those implementing moderate levels of sanitation (15.4-17.3 kg).

Table 1. Mean oviposition on the various banana tissues (cv Nabusa, AAA-EA) in laboratory choice experiments (N = 10)

A. Total number of eggs

	Plant or residue age			
	Maiden	Fresh 1-2	Old 14-30	Very old >30 DAH[1]
Corm	17.4a	4.9 cd	10.0 b	6.3 bc
Pseudostem		1.2 d	1.9 d	2.5 cd

B. Oviposition per female

	Maiden	Fresh 1-2	Old 14-30	Very old >30 DAH[1]
Corm	2.7a	2.3a	0.7 b	1.0 b
Pseudostem		0.2 b	0.6 b	0.9 b

Means with the same letter are not significantly (P<0.05) different by probability of LS means pair-wise comparison t-test.
[1]DAH = Days after harvest

Table 2. Mean distribution of eggs, larvae, pupae, teneral adults and adults by crop residue age (days after harvest - DAH) in farmers' fields

		Mean number of each banana weevil growth stage				
Age of residue (DAH)	n	Eggs	**Larvae**	Pupae	Teneral adults	Adults
0-7	120	2.4a	4.3a	0.7 b	0.5a	3.1a
8-14	30	1.5abc	3.1a	1.7a	0.7a	4.3a
15-30	30	1.7ab	4.3a	1.2ab	0.5a	3.1a
31-60	30	0.7 c	3.1a	1.2ab	0.5a	2.4a
61-120	30	0.9 c	2.4a	0.7 b	0.7a	4.3a

In columns, means (after square root (Ö**(x + 0.5)** transformation) followed by the same letter are not significantly (P<0.05) different by Ryan-Ginot-Gabriel-Welsch Multiple Range Test

Table 3. Number of eggs on standing (n=124) and prostrate (n=116) residue

Residue type		Age of banana residue (Days after harvest)				
		1-7	8-14	15-30	31-60	61-120
Standing	Corm	1.2a	1.0a	1.3a	0.7a	0.7a
	Pseudostem	1.2a	0.6a	0.4a	0.1a	0.7a
Prostrate	Corm	0.5a	0.4a	0.7a	0.1a	0.0a
	Pseudostem	0.0a	0.1a	0.0a	0.0a	0.0a

In columns, means with the same letter are not significantly (P>0.05) different by Ryan-Einot-Gabriel-Welsch Multiple Range Test

Table 4. Mean *Cosmopolites sordidus* larval and total larval to adult stage durations (days) on corms taken from different plant phenological stages and different aged residues.

	Larval duration	% Pupating	Larval to adult duration
Residue age			
Fresh	32.3 ± 0.61 c (30-51)	9.5	39.1 ± 0.64 b (30-42)[1]
Old	35.6 ± 0.65 b (30-39)	7.5	44.8 ± 0.78a (42-51)
Very old	39.4 ± 0.95a (33-45)	3.5	47.3 ± 1.01a (42-51)

Means in columns followed by the same letter are not significantly different (p > 0.05) by pair-wise comparison t-test of least square means. [1] numbers in parentheses = ranges

Table 5. Banana weevil corm damage (Least square means (+ S.E.)) by crop sanitation level over time in farmers' fields in Ntungamo sub-county, Uganda (1999-2002)

Sanitation level[1]	Total corm damage (%)			
	Baseline 1999	2000	2001	2002
L-L	3.6±0.42	4.0±0.30	3.5 ± 0.29	3.6 ± 0.56
L-M	3.8±0.27	3.0±0.20	3.6 ± 0.19	2.9 ± 0.41
L-H	2.7±0.52	1.6±0.37**	2.1 ± 0.36**	1.6 ± 0.73**
M-M	2.6±0.66	2.0±0.46*	2.5 ± 0.46	2.0 ± 0.93
M-H	2.1±0.74	1.6±0.52**	1.6 ± 0.52**	1.2 ± 1.04*
H-H	2.3±0.85	1.2±0.60**	1.6 ± 0.60**	1.5 ± 1.20

Means within a given row for each corm damage parameter are significantly different from baseline data by Dunnett's test (*p≤0.05, **p≤0.01), [1] Sanitation level: L=Low; M=Moderate; H=High. e.g. L-M: farmers who employed low sanitation during baseline survey and implemented moderate sanitation during study

Table 6. Mean height (cm), girth (cm) and number of functional leaves by sanitation level and sampling date in farmers' fields

Sanitation level[1]	Plant height (cm)						Bunch wt (Kg)
	Nov 99	Feb 00	May 00	Aug 00	Nov 00	Mar 01	Aug 00 to Mar-01
L-L	35a	142 b	209 b	231 b	300 b	346a	11.7 b
L-M	32a	146 b	216ab	250 b	319 b	355a	15.4a
L-H	24a	216a	222ab	255 b	320 b	364a	20.9a
M-M	41a	152 b	266a	304a	342a	342a	17.3a
M-H	45a	206a	278a	305a	362a	386a	20.4a
H-H	28a	179a	252a	299a	340a	345a	20.1a

Means in columns for each growth parameter followed by the same letter are not significantly (p>0.05) different by LSD.
[1] Sanitation level: L=Low; M=Moderate; H=High; e.g. L-M: farmers who employed low sanitation during baseline survey and implemented moderate sanitation during study

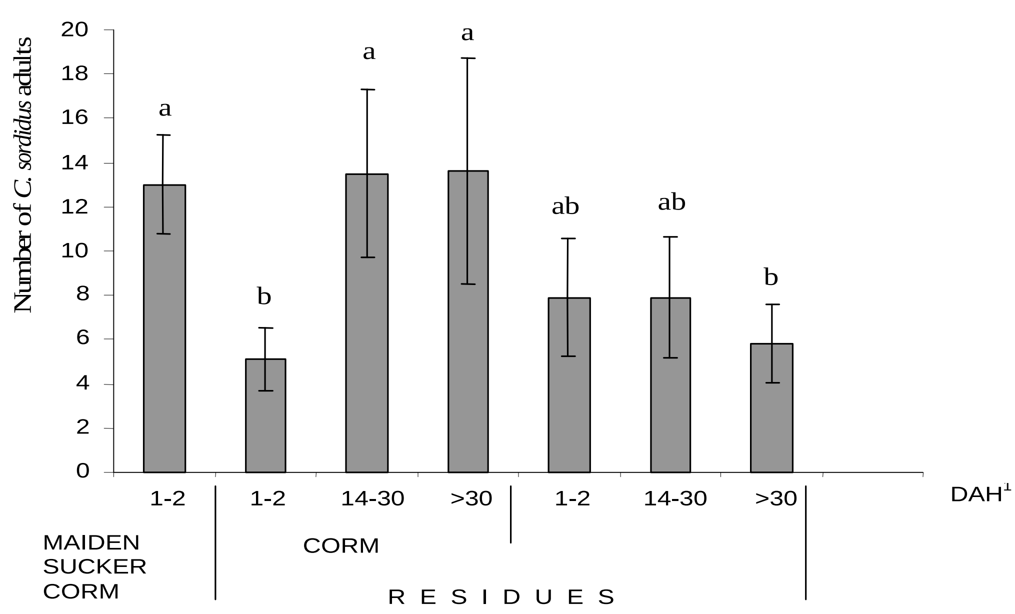

Figure 1. Number of adult weevils attracted to different aged host plant tissue (cv Nabusa, AAA-EA) in laboratory choice experiments. For each residue, age and type, means followed by the same letter are not significantly different by pair-wise comparison t-test of least square means

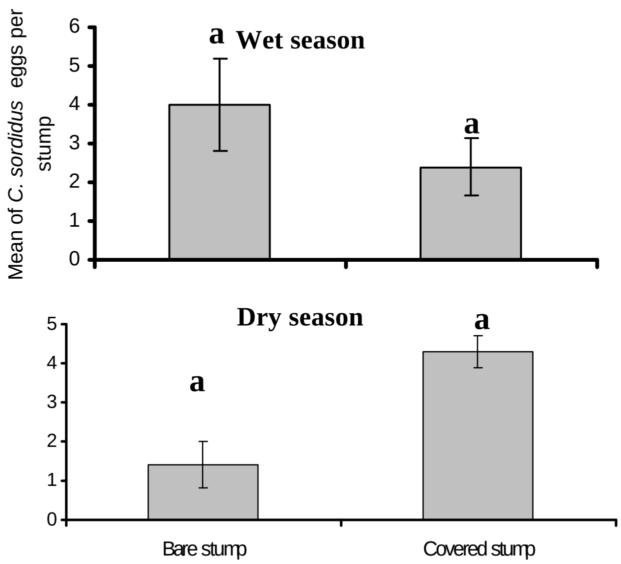

Figure 2. Effect of covering banana stumps cut below ground level with a 5 cm-layer of soil on *C. sordidus* oviposition in the wet and dry season at Kawanda. Means followed by the same letter are not significantly different ($p < 0.05$) by pair-wise comparison t-test of Least Square Means.

Farms with low levels of sanitation produced the lowest bunch weights (11.7 kg) (Table 7).

Discussion

Crop residues have been reported as refuges, food sources and oviposition sites for banana weevil. The role of crop residues in banana weevil population dynamics has been unclear. Nevertheless, crop sanitation has been recommended as a means of controlling banana weevil (Gold et al. 2001). However, little information is available on which types of residues are most attractive to banana weevil. Weevil use of older residues has been little studied. Such information might be used in recommendations on how farmers should time destruction of crop residues.

For example, many farmers in Bushenyi district in southwestern Uganda prefer to leave freshly harvested corm residues *in situ* to stabilize the banana mat and then dig them out several months after harvest, even though it is not certain if banana weevil attacks residues of this age. Therefore, information on the types of residues favoured by banana weevil and the timing of its attack could provide important insights into the management of crop residues for optimizing its effect on banana weevil population dynamics and pest status. The results in this study suggest that banana weevils are, in fact, attracted to crop residues of all ages. Our data from this study suggest that oviposition on residues peaks within the first month after harvest but continues for at least another three months.

A survey on crop sanitation practices as a control strategy against this pest in Ntungamo district revealed that 75% of the farmers practiced only low levels of sanitation, while 5% effected high levels of sanitation (Masanza, 2003). Farmers suggested two reasons for low adoption rates: (1) the practice was labour-intensive and removal of older,partially rotted stumps was less time-consuming than removing freshly harvested stumps; and (2) they were unclear of the importance of crop sanitation in reducing banana weevil pest problems. In addition, some farmers reported covering of banana stumps as a means of reducing banana weevil attack of crop residues, although they were not certain as to how well this worked.

Our results show that deep cutting of the corm and its removal may be beneficial in the wet season since banana weevil 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 and Gold, 2000). Banana weevil 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 this period. It is also likely that covering of banana stumps in the dry season preserves plant moisture, which probably also encourages banana weevil oviposition. If left bare, the corms dry up quickly, making them not suitable for weevils. In on-farm studies, higher banana weevil populations were found in low sanitation banana stands than in stands maintained at high sanitation. Farms employing different sanitation levels at the onset of the study had similar baseline numbers of banana weevil adults. Over time, populations increased in the low sanitation treatments, while those in high sanitation treatments remained at the same level. Similarly, farms increasing their sanitation levels from low to high tended to have lower banana weevil populations than farms maintaining low levels of sanitation. However, in both cases, effects were not manifest until weevil populations at the site underwent rapid increase, two years into the study.

Corm damage was also lower on farms with high sanitation than on farms with lower sanitation levels at the onset of the study. These differences increased over time. Farms that increased sanitation levels from low to high also displayed lower levels of damage than those that maintained low levels of sanitation throughout the study. Sanitation level influenced plant maturation times but had no effect on ultimate plant size. More importantly, higher sanitation resulted in higher yields, as reflected in higher bunch weights, although it was not clear to what extent yield differences reflected differential levels of banana weevil

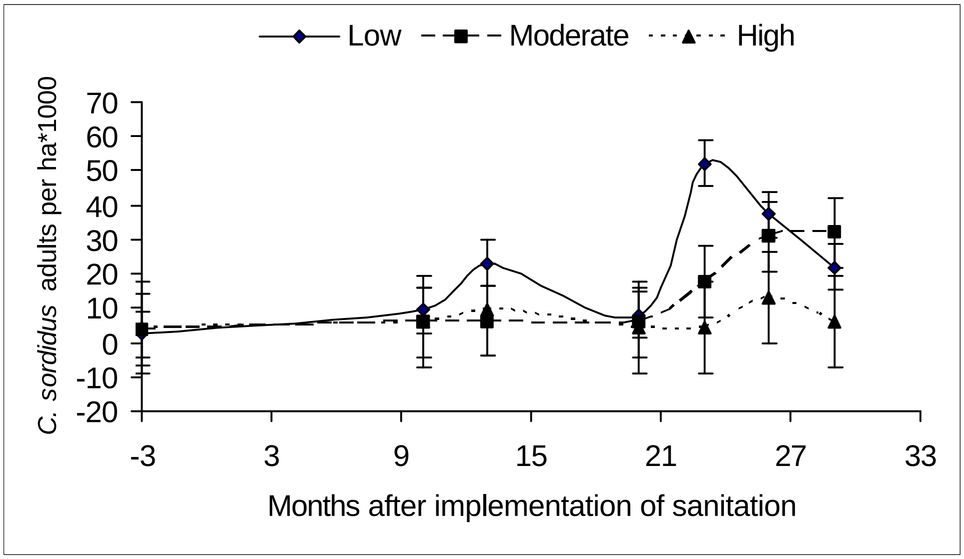

Figure 3. Weevil population density for farms maintained at original (baseline) sanitation levels, Ntungamo sub-county, Uganda

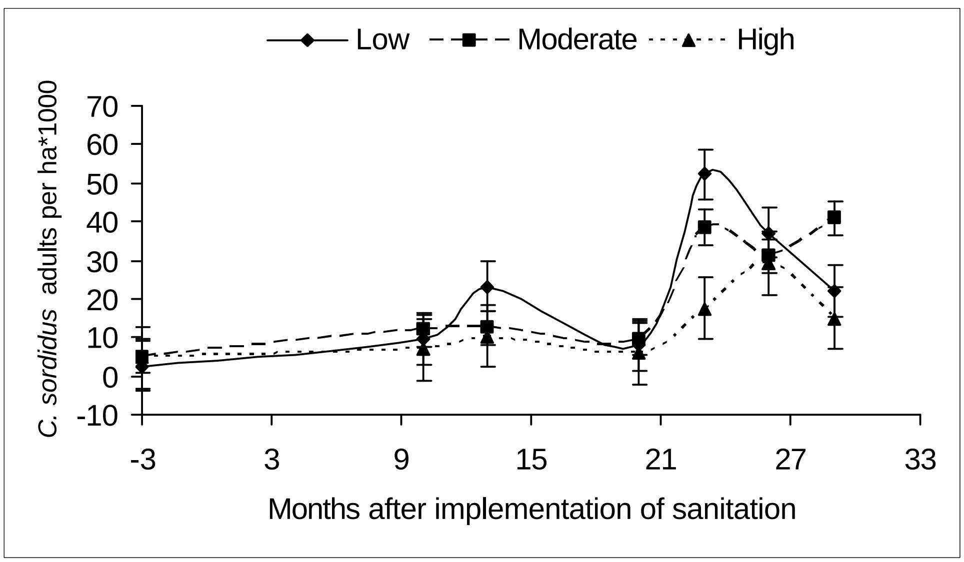

Figure 4. Weevil population density under different banana sanitation management levels for farms with low baseline management levels, Ntugamo sub-county, Uganda

damage or agronomic benefits of chopping and spreading residues as mulch (i.e. water conservation, faster breakdown of organic matter and more rapid availability of nutrients) (Salau et al., 1992; McIntyre et al., 2000).

These data suggest that destruction of crop residues under small farmer conditions can result in reduced banana weevil populations and damage, faster plant growth and higher yields. These results indicate that crop sanitation does have a beneficial effect on banana productivity. Therefore, we would recommend that farmers destroy their residues soon after harvest. We note, however, that farmers would need to weigh the increased labour costs against the benefits accrued.

Conclusion

In summary, our results suggest that all stages of residues, including those 120 days old and in deteriorated states, serve as hosts for banana weevil and that reproductive success is similar to that on growing plants. Even if only a few larvae survive to reproductive stage, their contribution to population increase can be significant. This is because weevils can live up to four years (Gold et al., 1999c), and females may lay eggs throughout their lifetime. Therefore, banana crop residues should probably be destroyed soon after harvest.

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 banana weevil time to oviposit, before the residues are subsequently destroyed. This will help reduce attack on standing plants.

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