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Economic Importance of Sweetpotato Weevil, *Cylas puncticollis* B. (Coleoptera: Curculionidae) and its Management in Eastern Oromiya, Ethiopia

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ABSTRACT

Field experiment was conducted with an objectives to estimate losses caused to sweetpotato due to *Cylas puncticollis* damage and devise integrated management options for the pest in eastern Ethiopia. The study was conducted at Haramaya University in eastern Ethiopia during the rainy season (June-Nov.) of 2011. The experiment was laid-out in Randomized Complete Block Design (RCBD) with three replications in a factorial arrangement. The factors were; three levels of cropping systems (sole sweetpotato (as control), sweetpotato intercropped with maize and sweetpotato intercropped with haricot bean), three levels of earthing-up (1x, 2x and 3x) and two levels of harvesting periods (prompt and 1 month delayed harvesting). Data collected were number of damaged and health storage roots, weight of healthy and damaged roots and yield of maize and haricot bean. These data were analyzed using SAS version 9.2 and means were separated using Least Significant Differences (LSD). Results of the studies suggested that the three way interaction effect was highly significant ($p<0.01$). Sweetpotato intercropping with maize, three times earthing-up and prompt harvesting has reduced percentage weight loss from 68.28 to 8.46% and yield loss from 70 to 22.26%. The highest (1.53) Land Equivalent Ratio (LER) was obtained from sweetpotato-haricot bean intercropping followed by sweetpotato-maize (1.28) cropping system. Similarly, cost-benefit analysis showed sweetpotato intercropped with haricot bean resulted in high economic profit than sweetpotato intercropped with maize and monoculture. Therefore, integrated use of the three cultural practices favorably reduced weevil's impact on sweetpotato and resulted with higher economic benefit. Hence, sweetpotato farmers are advised to use these eco-friendly economical tools in area where *C. puncticollis* is economically important insect pests of sweetpotato.

Key words: *Cylas puncticollis*, IPM, land equivalent ratio, yield loss, sweetpotato weevil

INTRODUCTION

In Ethiopia, Sweetpotato Weevil (SPW) (*Cylas puncticollis* Boheman) ranks the number one constraint for sweetpotato production (Fite *et al*., 2014) followed by sweetpotato virus diseases. *C. puncticollis* is an economically important and a serious pest of sweetpotato in eastern Oromiya in general and East Hararge in particular. This insect limits sweetpotato production by damaging vines, tubers and occasionally the foliage, reducing both yield and quality of the crop. Some control practices like chemical control and biological control are ineffective due to the cryptic feeding nature of the pest (Smit *et al.*, 2001).

C. puncticollis causes 60-70% yield loss in East Africa (Kabi *et al.*, 2001). This indicates that SPW is the main problem that hinders sweetpotato production in the region. However, crop loss due to a given insect pest could vary from place to place, time to time, crop to crop and even at different stage of the crop phenology. This demands loss assessment studies to be conducted continuously to develop sound pest management tools. Some cultural practices like intercropping, earthing-up and prompt harvesting were found to be effective in the management of *C. puncticollis* (Emana, 1990; Fite *et al.*, 2014).

The role of intercropping in reducing the infestation of SPW was previously reported by Alexander (1992), Rao (2005) and Rao *et al.* (2006). For instance, Frank and Liburd (2005) found reduced number of *Bemisia tabaci* and aphid in more diverse cropping systems involving squash, living mulch and buckwheat indicating the importance of cropping system for the management of crop pests. Earthing-up prevents exposure of tubers to weevil infestation by thickening the soils around the tubers and filling up the soil cracks, so that the adult *C. puncticollis* cannot reach tubers to cause damage (Macfarlane, 1987; Emana, 1990; Palaniswami and Mohandas, 1994; Fite *et al.*, 2014). Timely harvesting is another cultural practice that has been used for sweetpotato weevil management. It has been reported that weevil's populations build up when harvesting is delayed because it allows continuous reproduction on available food (Emana, 1990; Ebregt *et al.*, 2004; Kabi *et al.*, 2001; Fite *et al.*, 2014). However, the loss SPW causes to sweetpotato and integrated effect of these cultural practices have never been experimented in eastern Ethiopia for SPW management. Hence, there is a need to estimate yield losses of sweetpotato due to *C. puncticollis* damage in eastern Ethiopia and test the effectiveness of the integrated impact of these three cultural practices on SPW.

MATERIALS AND METHODS

Description of the study area: A field experiment was conducted during the rainy season of 2011 (June to November) at Haramaya University experimental field. The farm is located at an altitude of 1950 m above sea level and lies at 9°6' N and 41°8' E in the eastern part of Ethiopia. The station lies in the semi-arid belt of the eastern rift valley escarpment with a long-term average rainfall of 612 mm. The soil is classified as Eutric Regosol with a gentle slope (3-8%). The texture and structure of the topsoil (0-30 cm) are sandy loam and sub angular blocky, respectively. The soil has an average pH (H_2O 1:2.5) of 8.54 and organic matter content of 1.94% (0-15 cm) and 1.84 (15-30 cm). The mean annual rainfall is 520 mm and mean maximum and minimum temperatures range from 28.1-34.6 and 14.5-21.6°C, respectively (Belay, 2002).

Treatments and experimental design: The combined treatments consisted of three levels of cropping systems (sole sweetpotato (as a control), sweetpotato with maize and haricot bean intercropping), three levels of earthing-up (1, 2 and 3 times earthing-up) and two levels of harvesting periods (prompt and one month delayed harvesting). Sole haricot bean and maize was also planted for yield comparison on the same area. The treatment combinations (Table 1) were laid-out using Randomized Complete Block Design (RCBD) in factorial arrangement with three replications. Each plot size was 3 m width and 3.6 m length. The spacing was 60 cm between rows

Table 1: Different factors and treatment combinations*

		Earthing-up frequencies		
Cropping system	Harvesting period	1×(30DAP**)-E_0	2×(30 and 60DAP)-E_1	3×(30, 60 and 90DAP)-E_2
Sole sweetpotato (S_0)	Prompt harvesting (P_0)	$S_0P_0E_0$	$S_0P_0E_1$	$S_0P_0E_2$
	Delayed harvesting (P_1)	$S_0P_1E_0$	$S_0P_1E_1$	$S_0P_1E_2$
Sweetpotato+maize (S_1)	Prompt harvesting (P_0)	$S_1 P_0E_0$	$S_1 P_0E_1$	$S_1P_0E_2$
	Delayed harvesting (P_1)	$S_1P_1E_0$	$S_1P_1E_1$	$S_1P_1E_2$
Sweetpotato+ haricot bean (S_2)	Prompt harvesting (P_0)	$S_2P_0E_0$	$S_2P_0E_1$	$S_2P_0E_2$
	Delayed harvesting (P_1)	$S_2P_1E_0$	$S_2P_1E_1$	$S_2P_1E_2$
Sole haricot bean and sole maize	***LER and MAI			

*S_0: Sole sweetpotato, S_1: Sweetpotato intercropped with maize, S_2: Sweetpotato intercropped with haricot bean, E_0: One time earthing-up, E_1: Two times earthing-up, E_2: Three times earthing-up, P_0: Prompt harvesting, P_1: Delayed harvesting, **DAP: Days after planting, ***LER and MAI: Land equivalent ratio and monetary advantage index

and 30 cm between plants for sweetpotato. The spacing for haricot bean was 10 cm between plants and 60 cm between rows and spacing for maize was 15 cm between plants and 60 cm between rows. The spacing between blocks and plots were 2 and 1 m, respectively.

Planting materials, field preparation and its managements: A sweetpotato variety, Barkume; an early maturing variety of maize, Katumani and haricot bean variety, Kufanzihki were used for the experiment. For this study, 30 cm with 3-4 nodes of the top vine/middle vine parts of Barkume variety was used. The intercrops (maize and haricot bean) were planted on the two sides within sweetpotato rows (as mixed intercropping) on the same day after plowing, disking and ridging of the experimental field. First and second land preparations were done at two week's interval to facilitate organic matter decomposition of the soil. Land was prepared by ploughing using tractor and any residuals of the previous remains were collected from the plowed land and buried, seed bed were also prepared. After manual planting, light hoeing was used to remove weeds, diseased plants and off types.

Data collection

Percentage weight loss: At harvest, the weight of roots with sweetpotato damage symptoms and healthy roots were recorded. Then percentage weight loss was expressed using a following equation:

$$P = \frac{l}{t} \times 100$$

Where:

P = Percentage weight loss
l = Weight of damaged root
t = Total weight of root (sum of damaged and healthy roots)

Yield loss: After measuring the rooting characteristics, all plants on the two sample ridges were removed and counted. The root tubers on these plants were then dug out, counted and weighed.

The tubers were later separated into weevil infested and non-infested groups and counted. Then after, yield losses due to the weevils were determined by measuring the total weight of all the tubers, the weight of the *Cylas* damaged tubers and then the weight of the remaining edible portion of the *Cylas* infested tubers after the damaged parts were cut off. Yield losses due to *Cylas* weevil damage were then expressed as percentages using the equation (Kabi *et al*., 2001):

$$\text{Yield loss} = \frac{\text{TW} - \text{CW}}{\text{TW}} \times 100$$

Where:
TW = Total tuber weight
CW = Clean tuber weight

Evaluating the productivity of intercropping

Land Equivalent Ratio (LER): One of the main benefits of intercropping is an increase in yield per area of land. Following harvesting, all the crops were weighed to compare yields of monocropped and intercropped fields and then LER was calculated. The LER can be calculated using any measure of units (Willey, 1985). In this experiment, the LER is calculated by dividing the amount of the intercropped yield by the amount of the monocropped yield for each crop in the field or by adding the partial LERs together to find the total LER. In effect, if LER is greater than one, there is yield advantage, if it is equal to one, there is no yield advantage and if it is less than one, there is yield disadvantage because of intercropping. Thus, the Land Equivalent Ratio (LER) was calculated for each plant population using the formula developed by Sullivan (2003) and Ossom (2005) as follows:

$$\text{LER} = \frac{\text{Yield of crop A mixture}}{\text{Yield of pure crop A}} + \frac{\text{Yield of crop B mixture}}{\text{Yield of pure crop B}}$$

Monetary index: The most important part of recommending a cropping pattern is the cost:benefit ratio, more specifically total profit, because farmers are mostly interested in the monetary value of return. The yield of all the crops in different intercropping systems and also in sole cropping system and their economic return in terms of monetary value were evaluated to find out whether yield are profitable or not. The monetary index (Gomez and Gomez, 1983) was used to evaluate the yield advantage of each intercropping treatment that was obtained by subtracting the total cost of production from total economic value of the produce from each cropping system. This was calculated with Monetary Advantage Index (MAI). It is expressed as:

$$\text{MAI} = \text{Pab} + \text{Pba} \times \frac{\text{LER} - 1}{\text{LER}}$$

Where:
Pab = Pa×Yab
Pba = Pb×Yba
Pa = Price of species ‘a’
Pb = Price of species ‘b’

The higher the index value, the more profitable is the cropping system.

Statistical analysis: The recorded data were checked for normality before analysis. That data which assume normality were subjected to analysis of variance (ANOVA) and that which violate normality were transformed using square root transformation before analysis. Significant means ($p<0.05$) were separated using Least Significant Differences (LSD).

RESULTS AND DISCUSSION

Percentage weight loss: The three way interaction effects of intercropping, earthing-up and harvesting period was highly significant ($p<0.001$) in influencing the percentage weight loss of sweetpotato due to *C. puncticollis* (Fig. 1).

The minimum (8.46%) percentage weight loss of sweetpotato tubers due to *C. puncticollis* was recorded when sweetpotato intercropped with maize was integrated with three times earthing up and the crop was promptly harvested ($S_1P_0E_2$) but this treatment combination was statistically non-significantly different from $S_1P_0E_1$ (sweetpotato intercropped with maize-prompt harvested-two times earthing-up) and $S_2P_0E_2$ (sweetpotato intercropped with haricot bean-prompt harvesting-three times earthing-up). On the other hand, maximum (68.28%) percentage weight loss of sweetpotato tubers due to *C. puncticollis* was recorded from $S_0P_1E_0$ (combined use of sole sweetpotato cropping, delayed harvesting and one time earthing-up) and followed by the combined treatment of $S_0P_1E_1$ (sole sweetpotato-delayed harvest-earthed-up two times).

Intercropping sweetpotato with maize and haricot bean resulted in lower weight loss of sweetpotato storage tubers when compared with sole sweetpotato cropping system. The higher loss of weight in sole cropping of sweetpotato as compared to intercropped sweetpotato in this study, may be due to the structural loss (internal and external damage) (Fig. 2), feeding and oviposition punctures by the adult and larval of *C. puncticollis*. The feeding further leads to the entry of

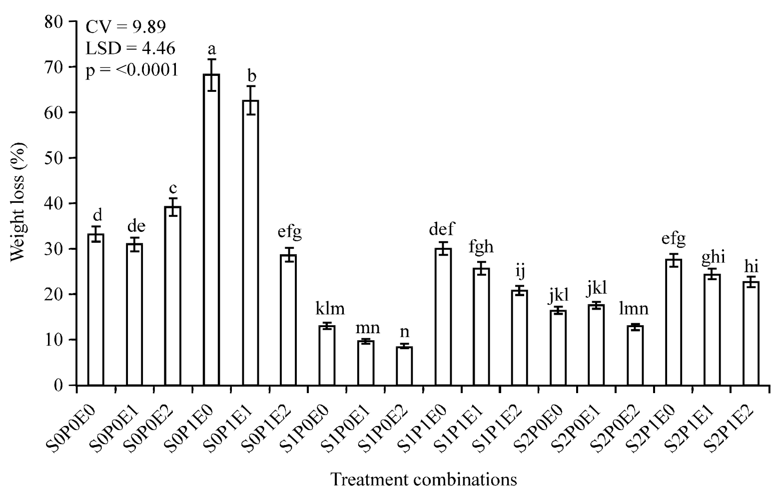

Fig. 1: Interaction effects of intercropping, earthing up and harvesting periods on the percentage weight loss of storage tubers of sweetpotato by *C. puncticollis* in eastern Ethiopia (2011). S_0: Sole sweetpotato, E_0: One time earthing-up, E_1: Two times earthing-up, E_2: Three times earthing-up, S_1: Sweetpotato intercropped with maize, S_2: Sweetpotato intercropped with haricot bean, P_0: Prompt harvesting and P_1: Delayed harvesting

Fig. 2(a-c): Sever external and internal damage to sweetpotato by *C. puncticollis* during rainy season of 2011 at Haramaya, Ethiopia (a) Whole storage root damage, (b) Damage on the tip of storage tubers and (c) Internal feeding by larvae filled with frasses and pupae of *C. puncticollis*

pathogens that facilitate the damaged tuberous tubers weight loss more rapidly than undamaged ones. This finding is in agreement with an earlier study by Strikeleather and Harrell (1990) who reported that undamaged tubers loss weight more slowly than damaged tubers. Physiological weight loss due to *C. puncticollis* infestation were the limiting factors for storage of sweetpotatoes and the damage may stimulate physiological deterioration leading to dehydration that also account for weight loss when the tubers are damaged by weevil. Mtunda *et al*. (2001) also observed that an increased weight loss, reduced shelf-life of root crops when the tubers are considered as unmarketable after a specified damage leading to weight loss.

In comparison to sweetpotato-haricot bean intercropping, sweetpotato-maize intercropping relatively gave high percentage weight loss when the tubers were harvested late (delayed harvesting). This may be due to the shading effect and high competition of maize for the same resources (nutrients, water and spaces) between the two crops in addition to weevil damage. This finding is in line with the finding of Alexander (1992) who reported less weight of fresh tubers in sweetpotatoes intercropped with corn.

Prompt harvesting gave relatively lower weight loss. On the other hand, delayed harvesting gave higher weight loss. The finding of Kihurani (2004) was in agreement with this finding in that he reported that early harvesting of sweetpotato reduced deterioration while delayed harvesting enhanced post harvest pathological decay of sweetpotato storage tubers. The increased weight loss when the time of harvesting was delayed for one month may be due to the high respiration rate due to damage by weevil and increased temperature which resulted in depletion of dry matter of the storage tubers. Higher temperatures induce higher respiration rates and subsequently faster physiological activities leading to the depletion of dry matter reserves and the senescence of cells (Amoah *et al*., 2011; Fleisher *et al*., 2008). They observed a decreased dry matter content of tuberous tubers from 36.2-32.4 g/100 g fresh weight on delaying the harvest date for one month.

Earthing-up the storage tubers also influenced the percent weight loss of sweetpotato tubers due to *C. puncticollis* in this study. The highest weight loss was recorded from one times earthing-up followed by two and three times earthing-up in that order. The more damage in one times earthed up soil may be because of the exposure of the roots to damage by weevils further exposing the root to biological and physical factors that lead to more deterioration of the roots leading to weight loss.

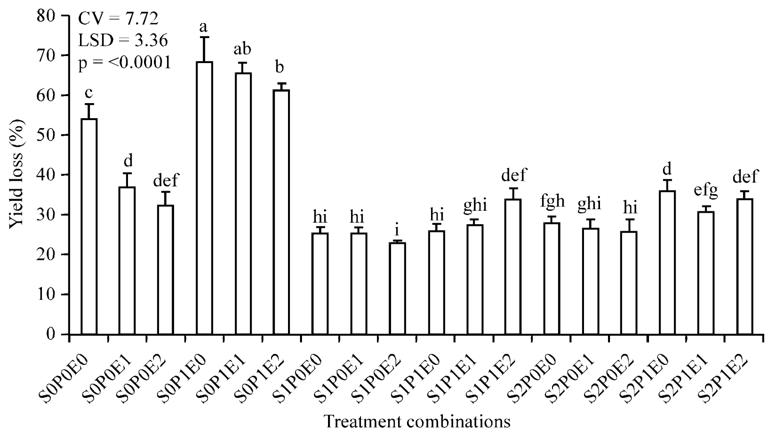

Fig. 3: Interaction effects of intercropping, earthing up and harvesting periods on the percentage yield loss of sweetpotato tubers by *C. puncticollis* at Haramaya, Ethiopia (2011). S_0: Sole sweetpotato cropping, E_0: One time earthing-up, E_1: Two times earthing-up, E_2: Three times earthing-up, S_1: Sweetpotato intercropped with maize, S_2: Sweetpotato intercropped with haricot bean, P_0: Prompt harvesting and P_1: Delayed harvesting

Yield loss: The three-way interactions effect of intercropping, earthing-up and harvesting period had highly significant effect ($p<0.001$) on the percentage of sweetpotato storage tubers yield lose due to *C. puncticollis* (Fig. 3).

The lowest percentage yield loss (22.26%) was recorded from $S_1P_0E_2$ (sweetpotato intercropped with maize-prompt harvesting-three times earthed-up) which was non-significantly different from $S_{1/2}P_0E_{0/1}$ (sweetpotato intercropped with maize/haricot bean-prompt harvesting-one/two times earthing-up), $S_1P_1E_{0/1}$ (sweetpotato intercropped with maize-delayed harvesting-one/two times earthing-up), $S_2P_0E_{1/2}$ (sweetpotato intercropped with haricot bean-prompt harvesting-one/two times earthing-up). On the other hand, the maximum (70%) yield loss was recorded from $S_0P_1E_0$ (sole sweetpotato cropping-delayed harvest-one time earthing-up) but statistically non-significantly different from $S_0P_1E_1$ (sole sweetpotato-delayed harvesting-one time earthing-up). Smit *et al.* (2001) reported similar results regarding sweetpotato weevils (*C. puncticollis* and *C. brunneus*) that cause upto 80% yield losses in areas where weevils are endemic. Kabi *et al.* (2001) also reported that sweetpotato weevils contribute 60-70% yield loss in East Africa. Therefore, the less yield loss in this experiment from the intercropped sweetpotato with maize in combination with three times earthing up and prompt harvesting was may be due to the low colonization of *C. puncticollis* in the intercropped crops, indicating that maize may have a repellent properties against insect pests, as earlier reports have shown. When the crop is delayed for one month's unharvested, the loss increased. This may be due the availability of sweetpotato tubers in the field which harbor the weevils supporting further reproduction serving as suitable environmental conditions for *C. puncticollis*. While main damage is on the tubers, yield losses also occur due to adults and larvae feeding on vines (Ekanayake *et al.*, 2001) which also confirm the present finding.

Productivity of sweetpotato intercropping

Land Equivalent Ratio (LER): In the present study, LER values were greater than one in the two intercropping systems which indicated that higher productivity per unit area and land use

Table 2: Economics of sweetpotato, maize and haricot bean as influenced by cropping systems (t ha^{-1})

	Root yield (t ha^{-1})	Grain yield (t ha^{-1})			
Cropping system	Sweetpotato	Maize	Haricot bean	LER	MAI US$ (ha)
Sole crops	31.25^{a}	3.84^{b}	2.6^{a}	1	789.45
SP+maize	24.71^{b}	1.89^{a}	-	1.28^{a}	904.48
SP+haricot bean	28.92^{a}	-	1.56^{b}	1.53^{a}	1156.21
$LSD_{(0.05)}$	2.65	0.25	0.25	NS	

Means with the same letter with in the same columns are not significantly different at $p<0.05$ (fisher's least significant difference test). Sole crops: Sweetpotato, maize and haricot-bean planted in pure stand, SP+maize: Sweetpotato intercropped with maize, SP+haricot bean: Sweetpotato intercropped with haricot beans, LER: Land equivalent ratio, MAI: Sum of the market value of sweetpotato at EBR 2.5 kg, haricot bean EBR 13 kg, maize at 5.6 kg (exchange rate of US$ to EBR 17.5)

efficiency was achieved by growing sweetpotato with maize/haricot bean than by growing in sole (Table 2). This confirms similar result, obtained by Adeniyi (2011) were in intercropping of pair rows of tomato with one row of cowpea and Njoku *et al.* (2007) were in sweet potato-okra mixture resulted in better LER. Lower LER (1.28) was obtained when sweetpotato was intercropped with maize than with haricot bean (1.53) (Table 2) but statistically non-significant. This is in line with the report of Njoku *et al.* (2007) who showed that sweetpotato-Okra intercropping is compatible and resulted in to 1.9 LER. Amede and Nigatu (2001) also agrees with this finding who observed a LER of 1.5 or greater when using the early maturing Katumani variety of maize is intercropped with sweet potato. The highest LER achieved from sweetpotato-haricot bean intercropping in comparison to maize intercropping was probably due to less competition between the two crops because haricot bean have the capacity to fix nitrogen through rhizobium bacteria. The presence of nitrogen fixation increases the amount of nitrogen in the soil available to the sweetpotato. Higher biological yield and efficient land use system was achieved with intercropping when compared to sole cropping of the different crops. Previous study also confirms the advantages of intercropping sweetpotato (Ossum *et al.*, 2006) or cereals with grain legumes. On the other hand, the lowest LER was obtained when sweetpotato was intercropped with maize, probably due to high competition and shading effect of maize on sweetpotato storage tubers.

Cost-benefit analysis of intercropping sweetpotato: The Monetary Advantage Index (MAI) illustrates that the greatest profit was obtained by intercropping sweetpotato with haricot bean and then followed by intercropping with maize resulting in a net gain of USA $1156.21 and 904.48 ha^{-1}, respectively than in their monoculture (Table 2). Previously, it was also reported that different cotton based intercropping systems increased farm income by 30-40% (Saeed *et al.*, 1999). The high profit from sweetpotato intercropping reflects that in addition to their effectiveness in reducing *C. punticollis* and other associated damage, they were also economical in increasing and diversifying farmer's income. This is in an agreement with previous studies of Nedunchezhiyan *et al.* (2011) who observed higher MAI value in sweetpotato-pea strip intercropping system.

CONCLUSION

The results of the present study suggest that yield loss under sole sweetpotato cropping system was higher than when it was intercropped with maize and haricot bean. Three times earthing up and prompt harvesting of sweetpotato (when it attains physiological maturity) were also found favourable for reducing the impact of weevil and increasing tuber yield. Integrated uses of these three cultural practices are recommended for weevil management to sweetpotato farmers of eastern Ethiopia. In addition, the economics study of intercropping of sweetpotato with maize and haricot bean suggest that higher productivity of sweetpotato can be achieved when sweetpotato is intercropped with these crops. Thus, it can be concluded that intercropping has an added advantage in terms of farmer's income apart from reducing weevil infestations.

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