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# Integrated Management of Sweetpotato Weevil (*Cylas puncticollis* (B.)) (Coleoptera: Curculionidae) at Chano Dorga, Southern Ethiopia

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## ABSTRACT

Sweet Potato Weevil (SPW) (*Cylas puncticollis*) (B.) is a destructive pest of sweet potato in Ethiopia. It causes severe damage to the tuber and infested tuber further produce bitter taste becoming unsuitable for human consumption and animal feed. This problem calls for *C. puncticollis* effective control measure (s). An experiment was carried out with the aim to identify effective control tools by integrating two cultural practices (Earthing-up and harvesting time). Sweet potato variety, Awassa-83, a moderately resistant variety to *C. puncticollis* was used for the study. Two factors: Earthing-up with four levels (no, 1x, 2x, 3x and no earthing-up) and harvesting time with three levels (prompt harvesting, one and two months delayed harvesting) making up 12 treatment combinations were tested. These treatment combinations were laid-out in a Randomized Complete Block Design (RCBD) with three replications. Marketable and unmarketable yield (t $ha^{-1}$), sweet potato damaged tubers, yield loss, percent damage and weevil density were assessed. The result obtained indicated that combination of three times earthing-up and prompt harvesting significantly reduced number of damaged tubers (25 $plot^{-1}$), SPW density (29.77 $plot^{-1}$), damage percentage (6.9% $plot^{-1}$), unmarketable yield (0.56 t $h^{-1}$) and yield loss (8.68%). These demonstrate the effectiveness of frequent earthing-up and prompt harvesting for management of SPW. Hence, integrated use of resistant variety, prompt harvesting and three times earthing-up can be recommended for the management of SPW in southern Ethiopia.

**Key words:** *Cylas puncticollis*, earthing-up, harvesting time, IPM, sweet potato weevil, sweet potato

## INTRODUCTION

Sweet potato (*Ipomoea batatas* Lam.) is an important food security crop in many of the developing countries (Korada *et al.*, 2010). The crop is grown both for home consumption and to supplement household income when sold in the local markets and in some urban center's (Stathers *et al.*, 1999). The use of sweetpotato as sources of family income is used to reduce losses to pests and provide opportunities to enhance food security and improve livelihoods. The area coverage of sweet potato production is increasing in sub-Saharan countries (FAO, 2005). FAO (2012) reported that over 100 developing countries of the world cultivate the crop and in more than 50 of these countries the crop is among the top five important crops. Sweet potato is known as an energy source better than (about 50%) the commonly consumed Irish potato (Bakumovsky, 1983). Apart from its high caloric content, sweet potato is also one of the cheapest potential sources of vitamin A which alleviate the problem of night blindness and infant mortality, which millions of children from sub-Saharan Africa are suffering from. Thus, the crop holds many desirable traits that positively contribute to food security and farmer's income in developing countries. The succulent, starchy storage tubers of sweet potato serve as a staple food, animal feed (Ruyiz *et al*., 1980; Lu *et al*., 1989; Woolfe, 1992) and to a limited extent the crop is used as industrial raw materials as a source of starch and for alcohol production (Winarno, 1982; Yen, 1982; Collins, 1984).

In Ethiopia, more particularly in the southern part of the country, sweet potato is intimately linked to the cultural and food habits of the society and it is considered as traditional food crop (Endale *et al*., 1994). It has been cultivated as food crop in Ethiopia for several years and over 95% of the crop produced in the country is grown in the South, South western and Eastern parts, where it has remained for centuries as an important co-staple food for the community (Terefe, 1987). Southern Ethiopia is the principal sweet potato growing region of Ethiopia and its economic impact in the region is considerable where it is used as a major source of food for the people (Ejigu, 1993). Sweet potato grows in different parts of the region mainly in Wolayita, Kanbata Tenbaro, Gamo Gofa and in other zones in smaller amount both as subsistence food crop and increasingly as cash crop to supplement house hold income (Ashebir, 2006).

In 2009/10 main cropping season, the production estimate of Central Statistical Authority of Ethiopia indicated that 53,465.22 ha of sweet potato were cultivated, producing 450,762,800 kg of tubers with 8431 (kg $ha^{-1}$) productivity (CSA, 2011). However, reports on research sites indicated that the potential productivity of the crop is by far more than this from improved varieties. This indicates that yield obtained by farmers is by far lower than the attainable yield obtained at research station. There are a number of constraints that hinder the production and productivity of sweet potato under farmer's conditions which could be broadly grouped under biotic and abiotic factors.

The major biotic constraints of sweet potato production are insect pests and viral infection (Chavi *et al*., 1997). In Ethiopia, a comprehensive list of insect pests infesting sweetpotato has been presented (Ferdu *et al*., 2009). Among the insect pests, 63.8% of farmers indicated sweet potato weevils (*Cylas* spp.) to be the most important in southern Ethiopia (Ashebir, 2006). *Cylas* spp. yield losses caused to sweetpotato ranges from 20-75% in Ethiopia (Emana, 1990); up to 80% in Uganda (Smit *et al*., 2001) and 5-50% in different states of India (Pillai *et al*., 1993). Infestation by SPW to sweet potato tuber, apart from direct injury and quantitative loss, causes qualitative loss and un-marketability of the produce because of unpalatable terpenoids production in response to infestation by the weevil (Stathers *et al*., 2003). The damaging stages of SPW are the larvae and the adults and they prefer to feed on the tuber, causing extensive damage in the field and storage. The principal damage of the pest is mining of the tubers by larvae. The infested tubers become dark in color and spongy in appearance with multiple holes. Weevil damage produces quantitative losses and aesthetically unappealing tuber which may be discolored and have bitter taste. The direct damage by SPW also invites indirect damage to the tubers by creating an entry holes for soil borne pathogens. SPW is a multi-voltine insect with several life cycles if the host plant is available and maintained in the field (Emana, 1987).

Despite years of intensive research, effective management practices for *C. puncticollis* are not available yet (Stevenson *et al*., 2009). Some of the recommended control practices, which are practiced in different parts of sweet potato growing regions are harvesting the crop as soon as tuber attains physiological maturity (Sherman and Tamashiro, 1954; Sutherland, 1986a; Talekar, 1991); early planting (Adhanom and Tesfaye, 1994; Tesfaye, 2002); resistant varieties (Emana, 1990; Temesgen and Tesfaye, 1995; Panda and Khush, 1995); insecticides (Emana and Adahanom, 1989; Tesfaye, 2002) and earthing-up and frequent irrigation (Emana, 1990). Korada *et al*. (2010) have made a comprehensive review of the different control measures against sweetpotato weevil. Although, early harvesting is recommended and storage in the field is discouraged, the traditional practice in the southern Ethiopia is underground storage and extended harvesting, in which plants are allowed to remain in the field for prolonged period to maintain a supply of tubers for long possible period for home consumption. Such extended harvesting scheme, however, poses problem in area where sweet potato weevil are prevalent by providing a continuum food for the weevil (O'Hair, 1991). The length of time the crop is left in the ground is one of the most significant factors which exacerbate the damage by weevils. The exact time of harvest differs with varieties and environmental conditions. In many traditional production practices, therefore, sweet potato is harvested when needed and there is no fixed harvesting time.

*Cylas puncticollis* is a difficult pest for conventional pest control measures using insecticides spray as the larvae feed in the storage tubers in the ground, or inside the woody base of the stems. This means that with the possible exception of systemic insecticides, which are costly and pose the risk of residual contamination of the tubers, there is no effective chemical control of the larvae, or of the other stages found within the plant tissue (Allard *et al*., 1991). In addition, widespread use of insecticides cause environmental hazards, resistance development, residues accumulation in the food and feed, harmful effect on non target organism and the cost of insecticides is getting too expensive from time to time for poor farmers (Dhuyo and Ahmed, 2007). Therefore, it was deemed necessary to develop eco-friendly, cost effective and compatible IPM measures for control of sweet potato weevils; hence this research was initiated with this objective.

## MATERIALS AND METHODS

**Description of the study site:** This experiment was conducted in Arbaminch zone at Chano Dorga Keble in Arba Minch Zuria on farmer's field, Southern Ethiopia. The site was located about 18 km North of Arbaminch town at an elevation of 1200 m above sea level. The area is known for its sweetpotato cultivation and hot spot for sweetpotato weevils (Emana, 1990; Ashebir, 2006). The area receives mean annual rainfall of 888.5 mm, mean maximum and minimum temperatures of 30.4 and 17.2°C, respectively.

**Experimental materials and design:** Sweetpotato variety Awassa-83, a moderately resistant variety to *Cylas puncticollis*, was used for this study. The experiment consisted of four levels of earthing-up (one time earthing-up i.e., one month after planting; two times earthing-up, v.z., one month and two months after planting; three times earthing-up, v.z., one month, two months and three months after planting and farmers practice, i.e., no earthing-up (used as a control)) and three levels of harvesting times (prompt harvesting, i.e., harvesting immediately when the crop attained physiological maturity; one month delayed harvesting and two months delayed harvesting). The treatment combinations (3*4 = 12) were laid-out in Randomized Complete Block Design using factorial arrangement with three replications. The plot size was 3×3 $m^2$ and with the spacing of 0.6 and 0.3 m between rows and plants, respectively.

**Data collected**

**Number of weevils:** Weevil count was started 30 days after planting and continued up to maturity at 15 days interval. For counting, sweeping net and visual count methods were used. Counting was done on six randomly selected plants per plot. At harvest, the tubers and vines (15 cm above the crown) of each of the six plants were dissected and the number of weevil larvae, pupae and adults were counted.

**Percentage infestation:** The infestation level of sweetpotato by sweetpotato weevil was determined from 12 randomly selected plants per plot and percentage colonization was computed as follows:

$$C = \frac{N}{T} \times 100$$

Where:
C = Percentage of colonization of the sweetpotato plant by sweetpotato weevil in a plot
N = No. of sample plants colonized
T = Total No. of plants per plot

**Percentage damaged tubers:** At harvest, the number of tubers damaged by sweetpotato weevil and healthy tubers were recorded and percentage damaged tubers were computed using the following equation:

$$PDT = \frac{I}{I + H} \times 100$$

Where:
PDT = Percentage of infested tubers
I = Infested tubers
H = Healthy tubers

**Marketable (healthy) tuber yield (MTY):** At harvest, the differentiated health tubers per plot (MTY) were weighed using bean balance. It was expressed as kg plot$^{-1}$ and converted in to t ha$^{-1}$.

**Unmarketable (infested) tuber (UMT):** UMT is the weight of infested tubers by sweet potato weevils. It was taken by weighting all the infested tubers collected from the plot by using bean balance and then expressed as kg plot$^{-1}$ and converted in to t ha$^{-1}$.

**Yield losses:** Yield loss was determined using the total weight of the harvested tuber per plot against the weight of clean/healthy tubers using the following equation (Kabi *et al.*, 2001):

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

Where:
TW = Total tuber weight
HW = Health or clean tuber weight

**Statistical data analysis:** Data were analyzed using analysis of variance (ANOVA), SAS Computer software version 9.2 (SAS, 2008) and MSTATC software's. Mean separation was carried out using Least Significant Difference (LSD) at 5% level of significance.

## RESULTS

**Effect of earthing-up and harvesting time on number of damaged sweetpotato tubers:** Analysis of variance showed significant ($p<0.05$) interaction effect of earthing-up and harvesting time with regard to number of tubers damaged by sweetpotato weevil at harvest (Table 1). The results obtained indicate that three times earthing up and prompt harvesting significantly gave the lowest number of damaged tubers (25 damaged tubers plot$^{-1}$). The next best treatment was obtained from three times earthing-up and one month delay harvesting (36.66 damaged tubers plot$^{-1}$). On the other hand, significantly highest numbers of damaged tubers were recorded from the interaction between farmer's practices and two months delayed harvesting (218.3 damaged tubers plot$^{-1}$) followed by no earthing-up (farmers' practices) and one month delayed harvesting (181.6 damaged tubers plot$^{-1}$).

**Effect of earthing up and harvesting time on percent damaged sweet potato tubers:** Percentage damaged tubers showed significant ($p<0.05$) interaction effect of earthing-up and harvesting time (Table 2). Three times earthing-up and prompt harvesting gave significantly lowest

Table 1: Effect of earthing up and harvesting time on No. of sweet potato tuber damaged by sweet potato weevil at Chano Dorga, Southern Ethiopia

| | Earthing-up (E) | | | | |
|---|---|---|---|---|---|
| Parameters | $E_1$ | $E_2$ | $E_3$ | $E_4$ | Mean (H) |
| **Harvesting time (H)** | | | | | |
| H1 | $63^{g}$ | $33.33^{i}$ | $25^{j}$ | $131.0^{d}$ | $63.4^{Z}$ |
| H2 | $101^{e}$ | $58^{g}$ | $36.66^{i}$ | $181.6^{b}$ | $94.5^{Y}$ |
| H3 | $145^{c}$ | $83.33^{f}$ | $43.66^{h}$ | $218.3^{a}$ | $122.5^{X}$ |
| Mean (E) | $103.2^{B}$ | $58.6^{C}$ | $35.11^{D}$ | $177.0^{A}$ | 93.5 |
| CV% = 4.12 | | | $LSD_{0.05}$=6.52 | | |

Means followed by the same letter within a table are not significantly different at 5% level of significance for interaction effects, E: Earthing-up, $E_1$: One time earthing-up, $E_2$: Two times earthing-up, $E_3$: Three times earthing-up, $E_4$: Farmers practice, H: Harvesting time, $H_1$: Prompt (immediately) harvesting, $H_2$: One month delayed harvesting, $H_3$: Two months delay harvesting, value with capital letters indicates the significance of main effect and small letters indicates the significance of interaction effect ($\alpha$ = 0.05)

Table 2: Interaction effect of earthing-up and harvesting time on percent damaged tuber/plot (%) at Chano Dorga, Southern Ethiopia

| | Earthing-up (E) | | | | |
|---|---|---|---|---|---|
| Parameters | $E_1$ | $E_2$ | $E_3$ | $E_4$ | Mean (H) |
| **Harvesting time (H)** | | | | | |
| $H_1$ | $28.6^{g}$ | $15.2^{j}$ | $6.9^{k}$ | $56.3^{d}$ | $26.7^{Z}$ |
| $H_2$ | $40.5^{f}$ | $24.5^{h}$ | $12.2^{j}$ | $70.2^{b}$ | $36^{Y}$ |
| $H_3$ | $61.3^{c}$ | $46.3^{e}$ | $21.2^{i}$ | $89.4^{a}$ | $54.5^{X}$ |
| Mean (E) | $44.2^{B}$ | $27.2^{C}$ | $13.9^{D}$ | $71.7^{A}$ | 39.4 |
| CV% = 4.9 | | | $LSD_{0.05}$ = 9.26 | | |

Means followed by the same letter within a table are not significantly different at 5% level of significance for interaction effects, $E_1$: One time earthing-up, $E_2$: Two times earthing-up, $E_3$: Three times earthing-up, $E_4$: Farmers practice, H: Harvesting time, $H_1$: Prompt (immediately) harvesting, $H_2$: One month delayed harvesting, $H_3$: Two months delay harvesting, value with capital letters indicates the significance of main effect and small letters indicates the significance of interaction effect at 5% level of significance

Table 3: Interaction effect of earthing-up and harvesting time on marketable tuber yield of sweet potato (t $ha^{-1}$) at Chano Dorga, Southern Ethiopia

| | Earthing-up (E) | | | | |
|---|---|---|---|---|---|
| Parameters | $E_1$ | $E_2$ | $E_3$ | $E_4$ | Mean for H |
| **Harvesting time (H)** | | | | | |
| $H_1$ | $6.69^{c}$ | $9.38^{b}$ | $15.63^{a}$ | $3.43^{e}$ | $8.78^{X}$ |
| $H_2$ | $5.15^{d}$ | $6.67^{c}$ | $14.40^{a}$ | $2.42^{ef}$ | $7.16^{Y}$ |
| $H_3$ | $1.62^{g}$ | $5.93^{cd}$ | $10.07^{b}$ | $1.18^{fg}$ | $5.20^{Z}$ |
| Mean (E) | $5.01^{C}$ | $7.32^{B}$ | $13.36^{A}$ | $2.49^{D}$ | 7.05 |
| CV% = 7.61 | | | | | |
| $LSD_{0.05}$ =1.235 | | | | | |

Means followed by the same letter within a table are not significantly different at 5% level of significance for interaction effects, $E_1$: One time earthing-up, $E_2$: Two times earthing-up, $E_3$: Three times earthing-up, $E_4$: Farmers practice, H: Harvesting time, $H_1$: Prompt (immediately) harvesting, $H_2$: One month delayed harvesting, $H_3$: Two months delay harvesting, value with capital letters indicates the significance of main effect and small letters indicates the significance of interaction effect at 5% level of significance

percentage damaged tuber (6.9%) where as maximum and significant percentage damaged tuber (89.4%) was obtained from farmer's practices integrated with two months delay harvesting. The next best treatment was obtained from the combination of three times earthing-up and one month delay harvesting (12.2%).

**Effect of earthing-up and harvesting time on marketable sweet potato tuber yield (t $ha^{-1}$):** Marketable sweet potato tuber yield was found significantly different ($p<0.05$) due to the interaction effect of earthing-up and harvesting time (Table 3). Maximum marketable tubers yield (15.63 t $ha^{-1}$) were harvested when three times earthing-up was combined with prompt harvesting, followed by three times earthing-up and one month delayed harvesting (14.4 t $ha^{-1}$). On the other hand, significantly lowest marketable tuber yield was recorded from the interaction effect of farmer's practices (no earthing-up) and two months delay harvesting (1.18 t $ha^{-1}$).

**Effect of earthing-up and harvesting time on unmarketable sweet potato tuber yield (t $ha^{-1}$):** The lowest unmarketable tuber yield was recorded from the interaction of three times earthing-up and prompt harvesting, 0.566 t $ha^{-1}$, in comparison with interaction of farmers practices with two months delayed harvesting which gave maximum unmarketable tuber yield, 6.38 t $ha^{-1}$ (Fig. 1).

**Effect of earthing-up and harvesting time on sweet potato tuber yield loss:** Analysis of variance showed significant ($p<0.05$) interaction effect of earthing-up and harvesting time with regard to percent yield loss of sweet potato tubers due to the infestation impact of sweetpotato weevil at harvest (Fig. 2). The result showed that three times earthing-up and prompt harvesting gave significantly lowest yield loss (8.68%) and farmers' practices with two months delayed harvesting gave significantly highest yield loss (88.11%) of sweet potato tubers yield. This indicates that the current practices of farmers' in sweet potato cultivation subjects the crop to 79.43% preventable yield loss by practicing three times earthing-up at monthly interval starting one month after planting and prompt harvesting alone.

**Effect of earthing-up and harvesting time on population density of weevil:** Sweet potato weevils count was found significantly different ($p<0.05$) due to the different treatment combinations

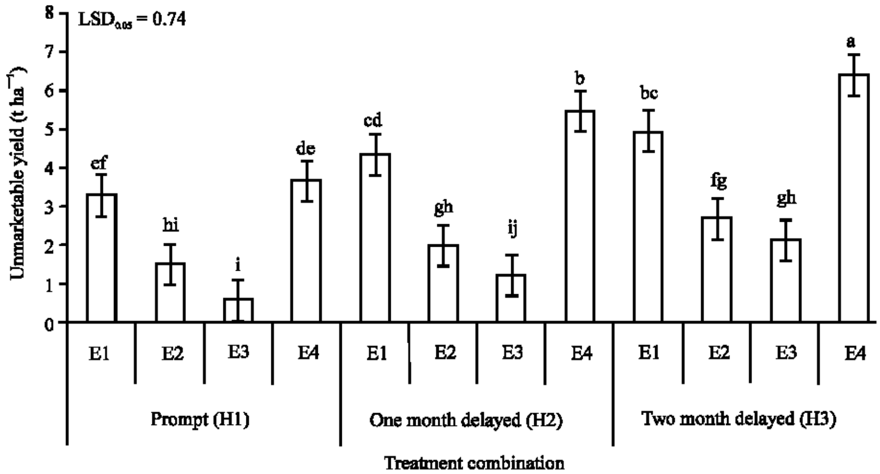


Fig. 1: Interaction effect of earthing-up ($E_1$: One time earthing-up, $E_2$: Two times earthing-up, $E_3$: Three times earthing-up, $E_4$: Farmers practice/no earthing-up) and harvesting time ($H_1$: Prompt (immediately) harvesting, $H_2$: One month delayed harvesting, $H_3$: Two months delay harvesting) on unmarketable tuber yield of sweet potato (t $ha^{-1}$) at Chano Dorga, Southern Ethiopia

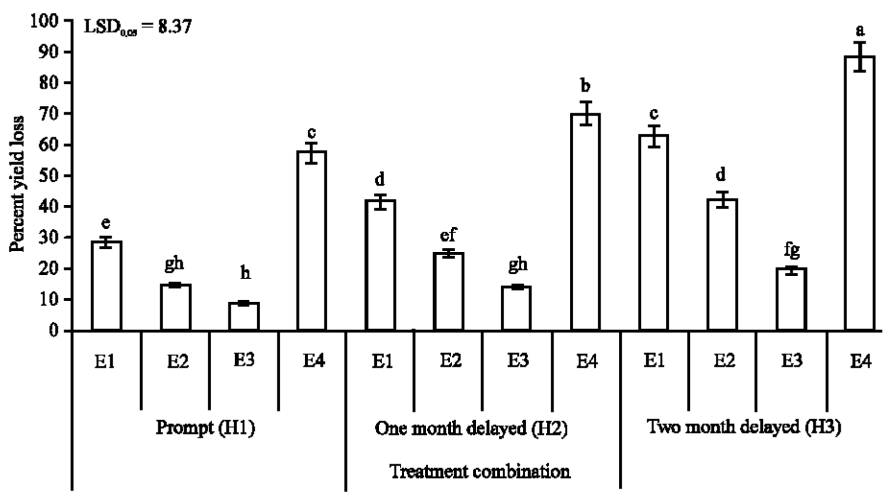


Fig. 2: Interaction effect of earthing-up ($E_1$: One time earthing-up, $E_2$: Two times earthing-up, $E_3$: Three times earthing-up, $E_4$: Farmers practice/no earthing-up) and harvesting time (H1: Prompt (immediately) harvesting, H2: One month delayed harvesting, H3: Two months delay harvesting) on percent yield loss of sweet potato due to sweet potato weevil at Chano Dorga, Southern Ethiopia

(Table 4). Significantly minimum numbers of weevils were obtained from plots that received three times earthing-up and prompt harvesting (29.77 $plot^{-1}$) followed by two times earthing-up and prompt harvesting (51.66 $plot^{-1}$). On the other hand, significantly the highest weevil populations were recorded from farmer's practices integrated with two months delayed harvesting (185.3).

Table 4: Interaction effects of earthing-up and harvesting time on population density of sweet potato weevils at Chano Dorga, Southern Ethiopia

| | Earthing-up (E) | | | | |
|---|---|---|---|---|---|
| Parameters | $E_1$ | $E_2$ | $E_3$ | $E_4$ | Mean (H) |
| **Harvesting time (H)** | | | | | |
| $H_1$ | $57.33^{fg}$ | $31.33^{h}$ | $29.77^{h}$ | $129.7^{c}$ | $62^{Z}$ |
| $H_2$ | $83.66^{e}$ | $55.33^{fg}$ | $51.66^{g}$ | $147^{b}$ | $84.41^{Y}$ |
| $H_3$ | $130.7^{c}$ | $97.66^{d}$ | $60.33^{f}$ | $185.3^{b}$ | $118.5^{X}$ |
| Mean (E) | $90.55^{B}$ | $61.44^{C}$ | $47.22^{D}$ | $154^{A}$ | 88.30 |
| CV% = 5.73 | | | | | |
| LSD0.05 = 8.578 | | | | | |

Means followed by the same letter within a table are not significantly different at 5% level of significance for interaction effects, $E_1$: One time earthing-up, $E_2$: Two times earthing up, $E_3$: Three times earthing up, $E_4$: Farmers practice, $H_1$: Prompt (immediately) harvesting, $H_2$: One month delayed harvesting, $H_3$: Two months delay harvesting, value with capital letters are for the main effect and small letter, CV and $LSD_{0.05}$ values are for the interaction effect

Table 5: Simple correlation coefficient among different variables studied at Chano Dorga, Southern Ethiopia

| Parameters | UMTN | MY (t $ha^{-1}$) | UY (t $ha^{-1}$) | PYL | PCW | SPWP |
|---|---|---|---|---|---|---|
| UMTN | 1 | -0.83* | 0.94** | 0.986** | 0.869* | 0.977** |
| MY (t $ha^{-1}$) | | 1 | -0.881* | -0.878* | 0.702* | -0.83* |
| UY (t $ha^{-1}$) | | | 1 | 0.94** | 0.787* | 0.898* |
| PYL | | | | 1 | 0.841* | 0.979** |
| PCW | | | | | 1 | 0.867* |
| SPWP | | | | | 1 | |

*Significant and **Highly significant, UMTN: Unmarketable tuber No., MY (t $ha^{-1}$): Marketable tuber yield, UY (t $ha^{-1}$): Unmarketable tuber yield, PYL: Percent yield loss, PCW: Percent colonization of weevils, SPWP: Sweet potato weevil population

**Simple correlation analysis:** Simple correlation analysis of the response variables showed significant and positive correlations between weevil population and unmarketable tuber yield (r = 0.898**), percent yield loss (r = 0.979**) and unmarketable tuber numbers (r = 0.977**) (Table 5). However, marketable tuber yield was negatively and highly significantly correlated with sweet potato weevil population (r = -0.830**). Similarly, marketable tuber yield was negatively and significantly correlated with (r = -0.878**) percent yield loss. This indicates that higher number of weevils in sweet potato agro-ecosystem is associated with increased yield loss and unmarketable tubers but decreased marketable tubers yield.

## DISCUSSION

In this experiment three times earthing-up and prompt harvesting reduces number of tuber damage from 218.3 to 25 tubers per plot. This is because hilling up prevented soil cracking that helps to hinder adult weevil movement to reach the tubers underground for egg laying and subsequent damage by larvae. Emana (1990) opined earthing-up of soil around the plant three times at monthly interval starting from the second month after planting significantly reduce the infestation of sweet potato weevil on sweet potato tubers as this practice hills up soil cracking thereby preventing the adult weevil to reach the tubers underground for egg laying. The same author demonstrated that such practice could protect sweet potato tubers from sweet potato weevils for more than six months. On the other hand, interaction of farmers practices with two months delayed harvesting gave high number of damaged tubers per plot (218.3) followed by farmers practice with one month delay harvesting (181.6). This is because weevils might undergo several life cycles which probably increased the weevil population, in the presence of tubers as a food that might supported more number of weevils ultimately leading to heavy damage of sweet potato tubers. Sherman and Tamashiro (1954), Sutherland (1986b) and CIP (1997) reported the relationship between damage caused by sweet potato weevil and harvesting time. According to their findings, infestation of sweetpotato by sweetpotato weevil increases as harvesting time delayed. Emana (1990) also demonstrated that delayed harvesting enhance the activity of sweet potato weevil. This work suggests that prevention of soil cracking by earthing-up the area around the plant and harvesting the crop at right time are an important method of reducing weevil damage. However, none of the previous researchers integrated different cultural practices for the management of sweetpotato weevil.

In this study, the highest mean percentage damage of tuber by weevil was recorded from interaction of farmers practices with two months delayed harvesting which was about 89.4%, where as the lowest percent damage (6.9%) of tubers by weevil was obtained from the integrated use of three times earthing-up and prompt harvesting. Thus, compared to the farmers practices (no earthing-up and delayed harvesting), three times earthing-up and prompt harvesting significantly reduced tuber infestation by sweetpotato weevil. This was due to the prevention of soil cracking by earthing up the area around the plant which prevented the tuber from weevil damage. Palaniswami and Mohandas (1994) suggested five times earthnig-up between 50-90 days after planting, at 10 days interval, for sweetpotato cultivation reduces weevil damage to the tubers. However, this may not be cost effective as it demands more labors. Tuber damage due to the insect was generally more sever during the dry season (Sutherland, 1986b). Sweetpotato weevils are particularly serious problems under dry condition because the insect reach tubers more easily when there are cracks that appear as the soil dries out. Teli and Salunkhe (1994) reported that weevils generally failed to penetrate wet soils but can penetrate dry soils.

In this trial three times earthing up and prompt harvesting increases tuber yield from 1.18 to 15.63 t $ha^{-1}$. This implies that yield of marketable tuber were significantly affected by the interaction of earthing-up and harvesting time. This might be because of the fact that earthing up the soil around the plant prevents the formation of soil crack which prevented the weevils reaching the tubers resulting to less damage of the tubers by weevils. Besides, this finding is in consistency with the finding of IITA (1975), which indicated that tubers with in the soil are less likely to be infested by the weevils. As a result of low infestation of sweetpotato weevil, there was a high marketable and low unmarketable yield of sweetpotato tuber harvested in this study when earthing-up was frequent and harvesting was prompt.

The lowest percentage yield loss due to sweetpotato weevil was obtained from the interaction of three times earthing-up and prompt harvesting while the highest was from farmers practices with two months delayed harvesting. This may be due to the fact that early harvesting of sweetpotato crop helps the crop to escape from weevil damage apart from limited movement of weevils in soil due to prevented cracks as a result of frequent earthing-up. This is in line with the report of Smit *et al.* (2001) from Uganda which confirmed that damage by sweetpotato weevil linearly increases with the delayed harvesting time beyond the physiological maturity of the crop because as harvesting time delayed the weevils may go under several life cycle which significantly increase the weevil population ultimately leading to heavy damage. The same authors also demonstrated that larvae tunnel through vines and tubers, which result in significant quality loss and possibly a direct yield reduction. Similarly, the report of Stathers *et al.* (2003) showed that

SPW infestation, even at low level, negatively impacts sweet potato tuber quality and marketable yield because infested tuber produce unpalatable terpenoids in response to weevil feeding. Sutherland (1986a) reported that loss of tuber weight occurred as a result of shrinkage due to loss of water through feeding and oviposition cavity made by the weevil as tubers were severely infested.

Minimum infestation of sweetpotato weevils were recorded from interaction of three times earthing-up and prompt harvesting indicating the positive contribution of earthing-up and harvesting time. This might be because of the fact that frequent earthing-up disturbed the life cycle of the weevil apart from hindering the movement of the adult weevils via cracks. On the other hand, no earthing-up integrated with two months delayed harvesting gave highest mean population of weevils. This practices lead to several life cycles for the weevils without obstacle during a prolonged storage period which increased their population. This finding is in agreement with Smit *et al.* (2001) from Uganda who reported damage by sweetpotato weevil linearly increase with the delay of harvesting time beyond the physiological maturity of the crop because as harvesting time delays the weevils may go under several life cycle which significantly increase the weevil population. The other reason may be the conduciveness of the environmental condition; the area is hot spot for sweetpotato weevil infestation (Emana, 1990). Besides, Allard *et al.* (1991) opined that dry condition facilitates SPW movement through cracks of the soils and causes serious damage.

## CONCLUSION

The conclusion to be drawn from the field study is that the interaction effect of earthing-up and harvesting time have potential role in reducing sweetpotato infestation by SPW. The two cultural practices have shown an immense advantage for sweetpotato producers in that their integration has resulted in low infestation of sweetpotato by sweetpotato weevil as compared to farmer's practices (no earthing-up and delayed harvesting). Earthing up soil around plant has most important impact on reduction of sweetpotato weevil infestation in field. Early harvesting play important role in reduction of weevil population in which plant escape from heavy infestation. The results reported in the present study indicated that combined effect of three times earthing-up and prompt harvesting showed significant reduction of weevils infestation and highly minimized number of damaged tubers; percent damaged tubers, yield loss and highly enhanced healthy tuber number and marketable tuber yield. Earthing-up the soil around the plant prevents the formation of soil cracks which avoid the damage by sweetpotato weevils. These practice hills up soil cracking thereby preventing the adult weevil's movement to reach the tubers underground for egg laying. This kind of cultural practice could protect sweetpotato tubers from sweetpotato weevils. Hence, farmers in southern Ethiopia can save their storage tubers of sweetpotato, capital and environment by using these cultural management practices of sweetpotato weevils. Thus, interaction effect of earthing-up and harvesting time to suppress sweetpotato weevils' infestation has been successfully demonstrated. Therefore, combination of three times earthing-up and prompt harvesting appears to be a valuable component in IPM programs against SPW pest.

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