

Field Evaluation of Major Tomato and Onion Insect Pests and Management Practices, In Rib Irrigation Site, Libo Kemkem District, South Gondar Zone, Ethiopia

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Abstract

Huge amount of losses due to herbivorous insects in different vegetable crops have been recorded worldwide. Tomato and onion are predominantly grown vegetables in the irrigation area of the present study site and damaged by insects. The main objective of the present study was to evaluate major insect pests that cause economic losses on tomato and onion and management practices in the study area. Data were recorded weekly starting from transplantation to plots of land on randomly selected tomato and onion plants. Numbers of insect were recorded per plant. Flying insects were trapped using sweeping net. Insect identification was carried out morphologically using standard identification keys. Insect pest

density of well managed and poorly managed fields was compared. Cutworm, moths, aphids, Africa bollworm, and onion thrips were the most common insect pests. There were 33.09 mean/plant onion thrips recorded on onion per m² of the plot. The analysis of well managed and poorly managed plots showed that 30.78% and 39.45% tomato fruits were damaged by insects respectively. Thrips caused 33.18% of yield loss on onion. Number of thrips per plant also varied with growth stage ($p < 0.05$). Onion growth stages of 9 to 11 weeks after transplanting were the most critical stage for thrips management where by suitable control measures needed.

Keywords: tomato, onion, insect pest, pest damage, management practice

Introduction

Herbivorous insects are said to be responsible for destroying one fifth of the world's total crop production annually and the severity increased in the tropics and tropics and sub-tropics (Kessler and Baldwin, 2002). According to CSA (2012), about 2,710 million tons of vegetables, root and tubers were produced on 541,000 ha, creating means of livelihood for more than 1 million households in 2010/2011. The production of vegetable crops is expanding with the expansion of irrigation schemes in the country (MOA, 2002). The average

productivity of tomatoes and onions in the year 2010-2011 was about 10.5 tons/ha and 10.8 tons/ha respectively (CSA, 2011). However, production of vegetables is low and insufficient due to insect pest attacks in the country. Shallot, garlic, potatoes, and chills are mainly produced under rain fed practices while tomatoes, carrots, lettuce beetroot, cabbage and onion are usually restricted to areas where irrigation water is available in Ethiopia (EIA, 2012).

Because of insect pests, huge amount of losses in different vegetable crops have been recorded in Ethiopia. *Thrips tabaci* is one of the major insect pests of onion crop recorded in the country. African bollworm was the major pest of tomato fruits both in irrigated and rain fed conditions this range occupied by the species includes tropical, dry, and temperate climate (Gashawbeza, 2006). For example, 36-39% loss occurred due to African bollworm in cabbage (Gashawbeza, 2006), and 26-57% loss in onion due to Thrips (Yeshtila, 2005). Shiberu (2013) indicated that *T. tabaci* is an important onion insect pest that destroys onion fields, especially in the dry seasons.

In Ethiopia, the economic threshold level of onion thrips was reported 5 to 10 thrips in one plant (Tadele, 2014). When vegetable crops infested early in the season, they remain small and never produce crop and if get infected later in the season,

they remain small and never produce crop and if get infected later in the season, fruits become unmarketable. In Toke Kutaye district, West Shoa, Ethiopia the yield losses due to onion thrips ranged from 0 to 36.44% (Shiberu, 2013).

Rib irrigation in Libo kemkem district is one of the areas growing vegetables affected by insects of different species. Many of the farmers in the Rib irrigation do not have detail information about field evaluation of tomato and onion insect pests attacking vegetables at different growth stages and management practices. Moreover, growers in the study site have no scientific justifications about the dynamics of the devastating insect pests across the seasons.

Therefore, in the present study, field evaluation of major tomato (*Lycopersicon esculentum* Mill) and onion (*Allium cepa* L.) insect pests and management practices were carried out.

Materials and Methods

Description of the study area

Libo Kemkem is one of the districts in South Gondar Zone of Amhara Regional State (fig. 1). The town of the district is Adis Zemen, which is located 645 kilometers from Addis Ababa

and 85 kilometer from Bahir Dar. It is located at 37015'36'' E to 38006'36'' E of longitude and 11054'36'' N to 12022'48'' N of latitude. The dominant crops growing in the study area include wheat (*Triticum sp.*), potato (*Solanum tuberosum*), barley (*Hordeum sp.*), teff (*Eragrostis sp.*), sorghum (*Sorghum bicolor*), bean (*Vicia fabia*), peas (*Pisum sativa*), Onion (*Allium cepa*), Tomato (*Solanum lycopersicum*) and maize (*Zea mays*).

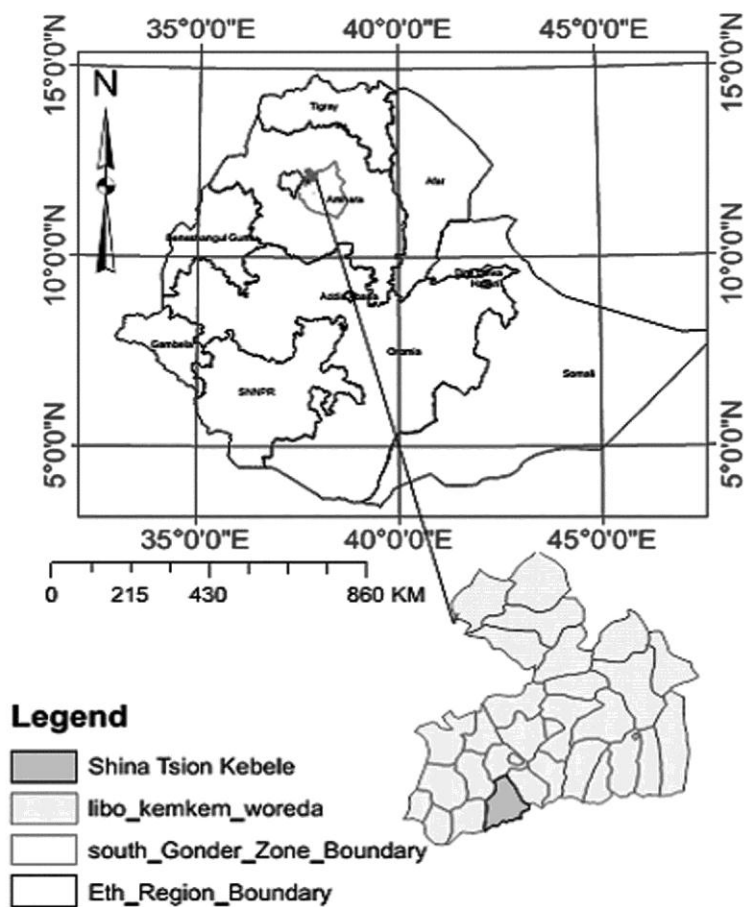


Figure 1: Map of the study area.

Woreda refer district and Kebele refers village

Experimental design

A longitudinal study was carried out to assess impact of insect pests and their management practices on onion and tomato fields from November 2016 to March 2017 in the study area.

Sample size and sampling technique

In the study area, 86 farmers were widely used irrigation for the production of tomato and onion crops. Among 86 farmers 38 farmers growing only tomato and 48 were growing onion during the study period. Based on the same transplanting date of onion and tomato, 20 farmers were selected purposefully. For data collection 1m by 1m plots of treated and untreated were arranged. Insect pest densities and degree of damage along with its effect on the crop were undertaken during each observation. All counts were performed in the morning at 12:00 up to 6:00. Sampling was done from November 2016 to March 2017 and was carried out weekly until harvest.

Assessment of insects' number and damage

Insect pests were evaluated at different growth stages of the crops starting from transplanting till harvesting. Leaves, stems, pods and fruits were examined from randomly selected ten plants per plot on the diagonal crosses method. The

The moving insects were collected using sweeping net. Insect population on the tomato and onion vegetable crops, damage inflicted to plants and insect developmental stages were surveyed on each plot. The difference between incidence and the damage in each plot at maturity stage was recorded. The collected insect pests were preserved with 70% ethanol in 20 ml vials and plastic bottles and also dead insects were collected packed individually for identification purposes.

Insect identification

Insects were identified morphologically by the identification keys of Gullan and Cranston (2000) using 10x magnifying hand lens.

Percent Fruit damage

Percent fruit damage was calculated by dividing number of fruits by the total number of fruits (Nasiruddin *et al.*, 2002).

$$\% \text{ fruit damage} = (B) \times 100 / A$$

Where A=total fruits (damaged + undamaged), and B=damaged fruits

Weight loss

Weight of damaged and undamaged tomato and onion were recorded for each plant of each picking in the study plots. The fruits damaged by insects were separated from healthy once and weighted and counted following Gwinner *et al.* (1996) and percent weight loss was calculated as weight of infested fruits multiplied by hundred and divided by total weight of fruits.

Total yield (kg ha⁻¹)

The weight of each picking was recorded individually for each sample and the total yield was calculated by adding the yield from all pickings. The yield was converted into per hectare basis with the following formula:-

$$\text{Yield (kg ha}^{-1}\text{)} = \frac{(\text{yield/plot}) \times 10000}{\text{Plot size}}$$

Incidence of onion thrips damage was determined by counting the number of damaged plants over the total number of plant per plot. Damage severity by Thrips was determined sampling ten plants randomly from the inner rows of each plot. The percentage of leaf surface showing thrips damage was assessed based on a scale of 1-5 (Smith *et al.*, 1994) where 1= no damage 2 = damaged up to 25%, 3 = damaged up to 26-50%, 4 = damaged up to 51-75% and 5 = damaged up to 75%.

According to HCDA (1991), harvesting was done by most farmers when 50-80% of the foliage had fallen over and the tops roots were cut off. Unmarketable bulbs includes decayed, diseased, physiologically disordered were identified from the total bulb yield.

Yield loss was calculated as the difference between mean yield of damaged and undamaged crop:-

$$\% \text{ yield loss} = \frac{(\text{Yield of undamaged} - \text{damaged crop}) \times 100}{\text{Yield of undamaged crop}}$$

Methods for evaluating farmers' management practices

In order to evaluate farmers' management practices, well-structured open and close ended questionnaire was prepared. The questionnaire was developed based on Lekei *et al.* (2014). Questions were translated into Amharic language for ease understanding by the respondents. The questionnaire was distributed to 20 farmers who transplanted tomato and onion on the same date.

Data analysis

Data analysis was done using SPSS version 16 statistical software. Percentage of damaged vegetables due to insects was analyzed using descriptive statistics. For socio-demographic data, descriptive statistics was used. Prevalence of insect pests collected at different weeks, damaged and undamaged fruits subjected to one way analysis of variance (ANOVA) and for the means separation the values of $P < 0.05$ were considered to be significant.

Results and Discussion

Occurrence of cutworm in immature stages of onion

Cutworm count per m² of the plot did not significantly different between week 1 and 5 growth stages presented in table 1.

Table 1. Occurrence of cutworm on onion per plot at different weeks after transplanting

Weeks after transplanting	Mean $\pm$ SE
Week 1	0.5 $\pm$ 0.17
Week 2	0.7 $\pm$ 0.21
Week 3	0.9 $\pm$ 0.23
Week 4	0.8 $\pm$ 0.20
Week 5	0.5 $\pm$ 0.17

Albarrak (2009) and Sarwar (2012) also reported that a mean number of cutworms per plant on the immature stages of onion were 0.33. After 5 weeks transplanting, cutworms were not observed. This might be due to the change of larvae into pupae. Researchers reported that larvae of cutworms' development lasted for 19.36 days (Vander Walt, 2008)

Onion thrips

Onion thrips has been observed after a month of transplanting of the target plant. Adult onion thrips count per plant was significantly different between managed and unmanaged plots ($P=0.0001$) and also among growth stages ($P=0.000$). On managed plots, a mean of 26.62 onion thrips/plant and unmanaged plots a mean of 39.56 onion thrips per plant were recorded.

At vegetative stage (table 2a), specifically at 6 weeks after transplanting, infestation of thrips was gradually increased with the growth of onion plants. The large number of thrips was recorded in the 13 weeks (table 2b), which is at the maturity stage of the onion.

Table 5 Occurrence of onion thrips on onion per plot at different weeks after transplanting

a) Vegetative stage

Weeks after transplanting	Mean±SE
Week 5	20±1.40
Week 6	40±1.40
Week 7	41±1.44
Week 8	58±0.87
Week 9	62±1.52
Week 10	78±1.8
Week 11	79±2.99

b) Maturity stage

Weeks after transplanting	Mean±SE
Week 12	33±1.09
Week 13	56±0.87
Week 14	27±1.48
Week 15	18±1.29

This result is in agreement with the work of Yeshitla (2005), which indicated that thrips population was low during the immature stages of onion and the maturity stages of the onions. Liu (2004) also reported that thrips infestation in the onion fields start to increase gradually with the growth of onion plants, and reach peak abundance in about 13 weeks of the onion plant.

Grasshopper

Another insect observed in the study site was grasshoppers. It was not found at the seedling/immature stages of onion plants. A few grasshoppers were found at the vegetative stage which tended to decline at crop maturity stage. This might be due to the plants become less and less attractive to the grasshoppers. Grasshopper mean density did not significantly difference between management ($P=0.3632$) and unmanaged vegetative stages of the onion plant ($P=0.1304$). In the managed plot, a mean of 0.2 grasshoppers per plant was recorded and on unmanaged plot a mean of 0.4 grasshoppers per plant were observed. Similar findings were reported by Andaloro and Shelton (2007) in onion fields during the vegetative stages.

Table 6. Occurrence of grasshopper on onion per plot at different weeks after transplanting

a) Vegetative stage	
Weeks after transplanting	Mean±SE
Week 4	0.3±0.15
Week 5	0.3±0.16
Week 6	0.4±0.16
Week 7	0.3±0.16
Week 8	0.4±0.16
b) Maturity stage	
Weeks after transplanting	Mean ± SE
Week 9	0.4±0.16
Week 10	0.5±0.16
Week 11	0.5±0.16
Week 12	0.3±0.15

Major tomato insect pests

A number of insect pests' species were recorded (table 7) on tomatoes in the study plots. The most serious pests include cutworm (*Agrotis ipsilon*) attacking seedlings, tomato fruit borer which is known as Africa boll worm (*Helicoverpa armigera* Hubner) that attacks fruits, and moths (*phthorimaea spp.*) also attacked fruits.

Table 3 Major insect pests recorded per plant on tomato at the study sites.

Common name	Scientific Name	Order/Family
Cutworm	<i>Agrotis ipsilon</i>	Lepidoptera/Noctuidae
moths	<i>phthorimaea spp.</i>	Lepidoptera/Gelechiidae
Onion thrips	<i>Thrips tabaci</i>	Thysanoptera/Thripidae
African boll worm	<i>Helicoverpa armigera</i>	Lepidoptera/Noctuidae

Cutworm

Cutworm count per m² plant was not significantly different ($P > 0.05$) between managed and unmanaged ($P=0.686$), and unmanaged ($P=0.0248$) tomato plants. A mean of 0.36 cutworms per m² was recorded on the unmanaged plot and 0.35 per m² on managed ones (table 4). Cutworm density was higher at the seedling stage of 2-3 weeks after transplanting, which later declined as plants grew older. Similar findings were reported by Bessin (2007) that two to three black cutworms were counted per m² on tomato fields.

Table 4 Occurrence of cutworm on tomato per plot at different weeks after transplanting

Weeks after transplanting	Mean±SE
Week 1	0.5±0.16
Week 2	0.7±0.15
Week 3	0.7±0.15
Week 4	0.4±0.16

Potato tuber moths (PTM)

Potato tuber moths larvae density per plant was significantly different between managed ($P=0.000$) and unmanaged plots of tomato plants. In the managed plots a mean of 4.54 moths per plot were recorded and a mean of 5.71 moths per plot was recorded in the unmanaged plots. No moths were observed at the seedling stage until 4 weeks after transplanting, but progressively increased at the vegetative stage and eventually decline in number at maturity (table 5). Maximum mean numbers of moths were counted at 9 and 10 weeks after transplanting.

Table 5. Occurrence of potato tuber moth larvae on tomato per plot at different weeks after transplanting per plot

a) Vegetative stage	
Weeks after transplanting	Mean±SE
Week 5	4.3±0.153
Week 6	6.3±0.152
Week 7	8.2±0.13
Week 8	10.1±0.10
Week 9	11.9±0.10
b) Maturity stage	
Weeks after transplanting	Mean±SE
Week 10	9.6±0.163
Week 11	4.8±0.133

Onion thrips

Number of onion thrips per plant was significantly different between managed and unmanaged ($P=0.000$) and also among growth stages ($P=0.0001$). Managed plots contained a mean of 4.99 onion thrips per tomato plant and unmanaged ones contained a mean of 6.21 onion thrips per plant ($P<0.05$). Thrips were not found at the seedling stages of tomato. Thrips infestation increased at vegetative and maturity stages (table 6

a and b). The current result was slightly different studied by Umeh and Manga (2002) who counted 8.3 thrips per plant at the seedling stage and none at maturity stages of the tomato plant.

Table 6 Prevalence of onion thrips on tomato per plot at different weeks after transplanting

a) Vegetative stage

Weeks after transplanting	Mean±SE
Week 8	2.4±0.163
Week 9	5.4±0.16
Week 10	8.2±0.133
Week 11	6±0.000

b) Maturity stage

Weeks after transplanting	Mean±SE
Week 12	9.6±0.163
Week 13	5.9±0.10

African boll worm (Tomato fruit borer)

Count of tomato fruit borer density per plant was not significantly different between managed and unmanaged plots. In the managed plots a mean of 0.7 fruit borers per plant

and 0.74 fruit borers per plant on unmanaged plots. The infestation of fruit borers gradually increased when tomato plants flowered and produced fruits (table 7 a and b). Similarly, Van Der Walt (2008) reported that feeding by larvae of the American bollworm on tomato increased when fruits produced after the end of flowering stage.

Table 7. Occurrence of fruit borer on tomato per plot at different weeks after transplanting

a) Vegetative stage

Weeks after transplanting	Mean±SE
Week 7	0.9±0.10
Week 8	1.9±0.10
Week 9	2.7±0.15

b) Maturity stage

Weeks after transplanting	Mean±SE
Week 10	2.6±0.163
Week 11	4.1±0.10
Week 12	4.1±0.10
Week 13	3.1±0.10

Similarly, Albarrak (2009) found that no fruit borers at seedling and vegetative stages, but counted a mean of 3.3 per plant at maturity stage. Likewise, Umeh and Manga (2002), a survey of some tomato producing areas of Nigeria indicated that the major insects attacking tomato included the fruit borer, grasshopper, aphids, and white fly were recorded at different growth period. Moreover, Gashawbeza Ayalew and Lemma Dessalegn (2004) also reported the severity of African bollworm on vegetable including tomato and onions.

Damage caused by major insect pests on onion

Cutworms

The larvae feed close to the base of a plant or under the soil level and cut the plant at the stems. When the stems fall, the worms consume more of the plant. Climbing species of cutworms can move to the leaves and buds of plants, where they sustain even more damage by chewing holes. Most destruction to plants occurs in the early growing season, when the seedlings are small and tender. The damaged caused by cutworm was 11% in managed and 15% in unmanaged plots in fields. Similar findings were reported by Nielsen (1999) in which shoot damage varied between the loss of 12% and 17% on managed field and 19% on unmanaged plants.

Leaf damaged by Onion thrips

A mean of 4.3 (51-75%) of the leaves were damaged on unmanaged fields and mean of 2 (25%) leaves were damaged on managed fields onion by onion thrips. Thrips use their rasping and sucking mouthpart to scrape the leaf surface and suck up the exuding plant juices. During the feeding practice, silvery-white, mottled lesions on the leaf surface produced.

The present study further illustrated that changes in abundance of thrips were occurred when changes in crop phenology occurred. In all cases, thrips population were first observed on onion plants four weeks after transplanting and increased at 7-8 weeks. This might be because of the fact that leaves at eight-leaf growth stage are succulent and thrips preferred to feed on such leaves. The maximum increment was observed 13 WAT per plant and eventually decreased when the crop maturity increased. When the crop maturity increased, the leaf nutritional value decline and becomes tougher and lignified such that it cannot be rasped by thrips so that adult thrips are forced to move towards newly developing leaves or other potential alternative hosts. This is in agreement with the result of previous study on onion, which indicated that at the final growth stage of onion, number of thrips is reduced because of a decline in nutritional value of the onion leaves (Workman and Martin, 2002).

The present study indicated that, higher numbers of thrips (33.09 mean/plant) were observed in the inner leaves of onion. This is in agreement with Soni and Ellis (1990) who stated that the area between the newest leaves concealed majority of juvenile and adult thrips. Reuda and Shelton (2000) also explained that thrips prefer to feed on young plant tissues in the newest emerged leaves. Feeding damage to onion plants were caused by both adult and larval thrips. Damage to photosynthetic areas occurs when tissues are ripped apart and depleted of plant juices. The removal of fluids results in the death of attacked cells. Moreover, Alson and Drost (2008) reported that thrips prefer to feed on the newly emerged leaves in the center of the onion necks and the majority of thrips would be at the base of the youngest leaves in the lower center of the neck.

Yield loss due to insect pest on onion

Onion bulb yield significantly varied between managed and unmanaged onion plant and unmarketable yield 39 q/ha and 56 q/ha, respectively (Table 8).

Table 8 Mean marketable and unmarketable onion yield in 1m² farm plot at Rib irrigation site in 2017

Type of plot	Marketable yield kg/m ²	Unmarketable yield kg/m ²
managed	2.17	0.39
unmanaged	1.45	0.56
t-value	8.76	-12.9
p-value	0.0001	0.000
Std error	0.3600	0.085

In the present study, the damage occurred by thrips caused on onion bulb yield loss of 72 q/ha (33.18%). This is in agreement with Yeshitla (2005) who recorded high yield loss when there is no management practice of thrips during different stages resulting in a total bulb yield loss of 35-45%, and marketable onion bulb yield loss of 44-53%. Moreover, Tsedeke (2001) indicated that onion bulb yield loss of 33.5% reported in the Awash Valley onion growing areas. Reuda and Shelton (2000) have also reported damages as high as 60% in tropical countries.

Damage caused by dominant insect pests on tomato in the study area

The plant damage incidence among managed and unmanaged plots recorded minimum percentage of infestation (13.3%) on managed plot and 15.7% on unmanaged plot. The damage effects of cutworms were relatively higher when plants are small, seedlings were often cutoff at ground level and if the soil around the plants were dug up to a depth of 5 cm, the characteristics of cutworm larvae could be found.

Cutworm hides during day time in cracks in the soil, become active at dusk, feed on leaves and also cut the tender stems of young and growing plants. It might be due to the absence of worm eating birds at night time. Then, they emerge at night and destroy vegetables and as a result farmers' loss one-third to one-half of their vegetables from cutworm ravages alone. Fowler and Lakin (2001) also reported that cutworms attacking vegetable in the night.

Larvae of cutworms hide under clods and in cracks in the soil in day time and appear at night, cutting off young plants near the ground. One larva often damages numerous plants in a row during a single night (Jim Chaput, 2005). Nielsen (1999) indicated that cutworms feed on plants by chewing, they vary as to damage done and host plants preferred.

Damage caused by tomato fruit borers (*Helicoverpa armigera*)

Fruit infestation

In the managed and unmanaged tomato fields there was significantly varied in mean number of fruits harvested and percentage fruit infestation by fruit borer (*Helicoverpa armigera*). In managed plots a mean of 11.6 fruits reordereed per plant and in unmanaged plots a mean of 9.1 fruits per plant was counted and fruit infestation by fruit borer was 30.78% and 39.45% respectively (table 8).

Table 8 Mean tomato fruits recorded per plant with in two different (managed and unmanaged) conditions at Rib irrigation area in 2017

Type of plot	Mean number of fruits per plant	Mean number of infested fruits per plant	% infestation
managed	11.6	3.57	30.78
unmanaged	9.1	3.59	39.45
t-value	5.1	-0.10	-5.1
p-value	<0.0001	0.9204	<0.0001
Std. Error	1.25	0.10	

According to Singh (2009), 30% loss of fruits was reported due to fruit worm infestation. Similar to the current finding, Sajjad (2011) indicated that the minimum larval population of the fruit borer was recorded to be 0.41 per plant on tomato fields. In addition, the maximum infestation was recorded to be 27.4% and minimum infestation of tomato fruit 26.3%.

Marketable and unmarketable yield of tomato fruit

There was significant differences ($P=0.0025$) between managed and unmanaged marketable yield. But there was no significant differences ($P=0.1743$) between managed and unmanaged marketable yield of tomatoes (table 9).

Table 9 Mean of tomato marketable and unmarketable yield in kg per plant

Type of plot	Marketable yield in kg per plant	Unmarketable yield in kg per plant
managed	6.2	2.5
unmanaged	4.9	2.3
t-value	3.74	1.42
p-value	0.0025	0.1743
Std error	0.6500	0.1000

In the present study, a maximum yield of 6.2 kg/plants was recorded while; minimum yield was 4.9 kg/plant. The percentage of weight loss of managed plot of tomato yield was 28.7% and unmanaged weight loss of tomato yield was 31.94%. Strinivasan and Sundara (2000) reported that 40 to 50% of fruits are damaged by this pest.

Farmers' management practices on tomato and onion vegetables

Table 10 presents the socio-economic characteristics of the respondents. Among the respondents, 75% of them were males while 25% were females. A good number of farmers (65%) in the study site are in their economic active stage. About 45% of the respondents had between 6 and 10 years of farming experience. When we look at the educational status, 50% of the farmers had no formal education. The management practices on tomato and onion reported by respondents in the study area (table 2) include more than half (55%) who lacks of training and do not participate in crop management practice by experts. About 70% of the respondent did regular monitor in controlling tomato and onion insect pests. More than half (60%) of the respondents were used a pesticide branded as Diazinon 50% E.C and 70% of the respondent have good management practices for the majority of insect pest occurred in the study site. Traditional management practice has been

observed including hand picking of larvae, uprooting and removing infested plants.

Table 10. Socio-economic characteristic of respondents

(N=20)

Variables		Percentage
Sex	Male	75
	Female	25
Age	<30	25
	31-35	40
	36-40	25
	>41	10
Marital status	Single	20
	Married	40
	Divorced	25
	Widowed	45
Educational status	No Formal Education	50
	Primary	25
	Secondary	10
	University graduate	5
Farming Experience	0-5	30
	6-10	45
	>11	25
Farm size in hectare	0.26-0.5	10
	0.6-1	25
	1.1-1.5	65

Table 11 management practices of respondents

variable		Percentage
Training on crop management experts	participant	45
	Not participant	55
Monitoring of pest	regularly monitor	70
	Not regularly monitor	30
Kind of pesticides used	Diazinon	60
	Dursben 48%	25
	Fentratayon 50%	45
Cause of insect pest occurrence	poor management practices	70
	Good management practices	30
Present status of pests	less damaged	60
	More damaged	40

The management practices of vegetable growers in the study area showed that people used pesticides to control insect pests. Geremew (2004) also reported that for management of cutworm control is currently based on heavy use of many insecticides. However, there is a need of integrated management options to reducing the risk of pesticide resistance development, reduce the impacts of the insecticide to environment, non-targeted organisms, beneficial insects such as natural enemies and human hazards.

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