

Experimental Analysis of Economic Action Level of Tomato Leafminer, *Tuta absoluta* Meyrick (Lepidoptera: Gelechiidae) on Tomato Plant under Open Field

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Abstract

Tomato leafminer, *Tuta absoluta* (Meyrick) is considered to be one of the major pests of tomato crop in Ethiopia. In tomato, economic impact is caused by larval which feeding leaves and fruits. Information on tomato leafminer economic injury levels (EILs) and economic thresholds (ETs) is relatively limited. Studies were conducted during 2015 to 2017 to determine EILs and ETs on open field is required for more effective management. The results from the current studies significant ($P < 0.05$) differences were observed among the treatments during the study periods. *T. absoluta* was highly infested the untreated control as compared with protected treatment. The mean value of marketable yield loss to the cost of insecticide application at one larva/plant was 3.61% and from untreated control was obtained 77.91% during 2015/16. Similarly, during 2016/17 at one larva/plant and untreated control marketable yield loss were observed 5.57% and 81.61%, respectively. The highest yield loss was observed at unsprayed control (24,577.84 kg/ha) followed by five larvae/plant (10,587 kg/ha) during 2015/16 while during 2016/17 the highest yield loss also observed in untreated control (26,593.08 kg/ha) followed by five larvae/plant. From this study the economic injury level of *T. absoluta* was 3.82 larvae per plant. Therefore, based on economic injury level, the economic threshold level was determined as at 2.87 larvae per plant.

Keywords: *Tuta absoluta*; Tomato; Economic threshold; Economic injury; Marketable yield benefit cost ratio

Introduction

Tomato, *Lycopersicon esculentum* (Miller) (Family: *Solanaceae*) is an important vegetables crop of Ethiopia. It is widely used in salad as well as for the culinary purposes. The popularity of tomato and its products continue to rise as it contains a significant source of Vitamins A, B and C [1]. Tomato is devastating by an array of pests; however, the major damage is caused by the Tomato fruit borer, *Helicoverpa armigera* (Hubner) (Lepidoptera: Noctuidae) and tomato leafminer, *Tuta absoluta* Meyrick (Lepidoptera: Gelechiidae). The Larvae of this insect pest reduce tomato yield 80 to 100% fruits were found to be damaged by this insect [2]. In very recent year, in Ethiopia *T. absoluta* is one of the most important and serious pests of tomatoes [3].

Study on economic threshold level is an important tool for the management of insect pests. Stern et al., [4] who formally proposed the concept of economic threshold levels as the number of insect (density or intensity). The management action should be taken to prevent the increasing pest population from reaching economic injury level. Way et al., [5] stated that, the development and implementation of economic thresholds is a rational approach to pest management designed to aid farmers in making pest control decisions. Hence, the economic threshold level of *T. absoluta* in Ethiopia is yet not studied.

Regular monitoring is of paramount importance in IPM to ensure timely intervention before economic damage occurs, thereby saving farmers unnecessary cost. The functional relationship between pest infestation levels and benefit from control measures can be visualized

as a benefit plane that shows increasing benefit with increasing infestation levels of either pest [6]. It is thus important to determine economic injury level for effective management of pests to prevent avoidable yield losses. With this background, the present study was conducted to determine the larvae of *T. absoluta* economic injury and economic threshold level in tomato under open field.

Materials and Methods

The experiment was carried out at West Shawa of central Ethiopia under open farmer's field during dry seasons of 2015/16 and 2016/17 using natural infestation by different levels of larval population to establish the economic injury levels of *Tuta absoluta*. The ETL was determined based on economic injury level and benefit cost ratio as suggested by Farrington [7]. The experiment was laid out in randomized complete block design (RCBD) with three replications. There were seven treatments consisted of six different larval densities i.e., 0, 1, 2, 3, 4 and 5 larvae per plant. When the number of larvae reaches each treatment spray with standard chemical was sprayed accordingly. The number of total and damaged leaves and fruits were counted and fruit yields weighed from each treatment. Relationship between the larval densities and the number of leaf and fruit damaged was worked out by correlation co-efficient and regression equations. Yield losses due to different treatments were derived by deducting the yield of the respective treatment from the yield of control (where no egg and larva protected treatment). The value of yield losses was determined according to the wholesale market price of tomato at current market situations.

Benefit cost ratio (BCR) was worked out as the ratio of the value of yield saved to the cost of insecticidal application. Standard chemical was considered for calculating the cost of insecticidal application.

Data collection

Regular periodical counts of the *T. absoluta* (eggs and Larvae) and number of damaged (leaves and fruits) were taken from 10 plants in each plot, where the leaves and fruits had checked for larvae. However, when the sprayable level was attained, the plots were sprayed one day later with the appropriate insecticides, according to the pest situation. Spraying was carried out using a knapsack sprayer. Finally yield data was taken to compare the treatments.

Data analysis

The collected data for each treatment was subjected to analysis of statistical software package [8] was employed for analysis of variance of the experiment. The economic injury level for *T. absoluta* larvae were calculated by fitting regression equation $Y=a+bx$, between larval

population levels and Benefit Cost Ratio. The larval density corresponding to unit Benefit Cost Ratio was the economic injury level and economic threshold levels were set at 75% of EIL [9].

Results

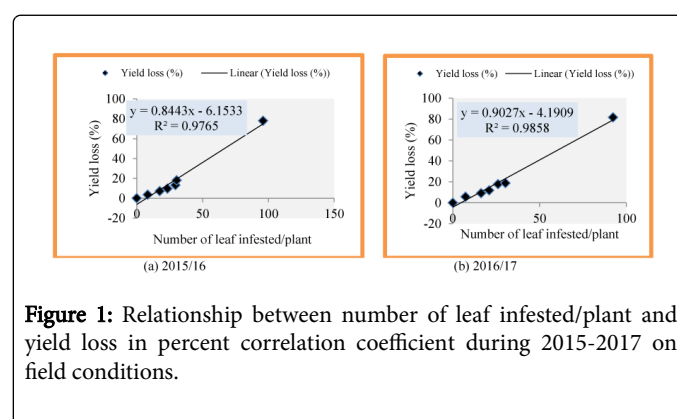
Yield and yield losses

A population density of one larva per plant caused about 6.33% leaf damage during 2015/16 which indicated 3.61% yield losses. In 2016/17, 8.03% leaf damage was observed which showed 5.75% yield losses (Table 1). The control (unsprayed) treatments were caused 50.76 leaf damaged during 2015/16 and 56.97% in 2016/17. The control treatments in both years revealed that 77.91% and 81.61% yield losses in 2015/16 and 2016/17, respectively. On the other hand, 5 larvae of *T. absoluta* per plant were showed 18.07% marketable yield losses were observed during 2015/16, in similar manner 5 larvae of *T. absoluta* per plant revealed that 18.61% marketable yield reduction during 2016/17.

Treatments	Year I (2015/16)			Year II (2016/17)		
	No. of leaves infested/plant	No. of fruit tunneled/plant	Marketable yield/plant in (kg)	No. of leaves infested/plant	No. of fruit tunneled/plant	Marketable yield/plant (kg)
T1	0.0e	0.0e	0.83a	0.0e	0.0e	0.87a
T2	8.33d	2.33de	0.80ab	13.33d	1.33de	0.82ab
T3	17.33c	3.33d	0.77abc	16.33d	3.33cd	0.79abc
T4	23.33bc	3.67d	0.75bc	21.0cd	4.67c	0.76bc
T5	29.33b	9.0c	0.72c	26.0bc	6.33bc	0.71c
T6	30.33b	12.33b	0.68c	30.37b	9.33b	0.70c
T7	96.0a	23.67a	0.18d	92.33a	26.67a	0.16d
LSD	7.77	3.16	0.1	6.89	3.17	0.07
MSE ±	4.33	1.76	0.06	3.83	1.77	0.04
CV (%)	14.8	22.66	8.11	13.86	23.92	5.5

Table 1: Infestation level of *T. absoluta* on tomato plants on field conditions in 2015-2017. Note: T1=0 larva density, T2=1 larval densities, T3=2 larval densities, T4=3 larval densities, T5=4 larval densities, T6=5 larval densities, T7=Control.

The relationship between *T. absoluta* number of leaf infestation and marketable yield loss percent was expressed by the regression equation $y=0.844x-6.153$ and $y=0.902x-4.190$ for years 2015/16 and 2016/17, respectively. A strong positive correlation was found between number of leaf infestation and marketable yield loss ($r^2=0.976$) and ($r^2=0.985$) during 2015/16 and 2016/17, respectively. However, increase in larval population per plant did show proportionate increase in marketable yield losses (Figures 1 and 2).



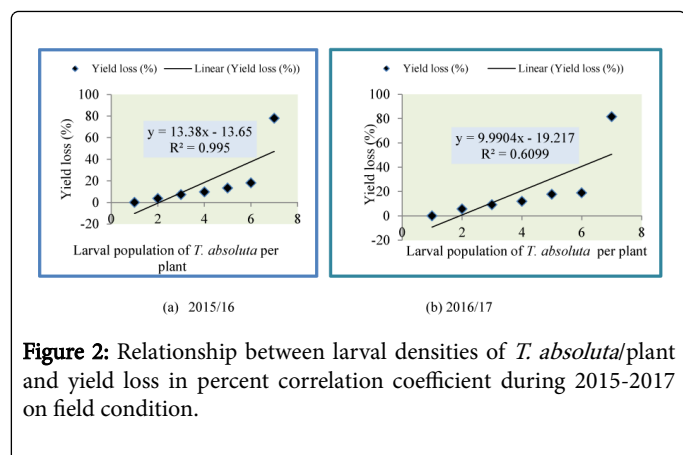


Figure 2: Relationship between larval densities of *T. absoluta*/plant and yield loss in percent correlation coefficient during 2015-2017 on field condition.

Economic threshold and economic injury level

A linear relationship between tomato yield and larvae of *T. absoluta* per plant was detected on field during 2015-2017. There was a significant linear relationship between larval infestation and marketable yield loss when tomato fruit and leaf were infested in larvae (Figures 2 and 3). The correlation between the observed and predicted values of marketable fruit weight was calculated for each data set to assess the fit of the model. However, the economic injury level (EIL) is often expressed mathematically by the following formula:

$$EIL = \frac{C \times N}{V \times I}$$

Where:

"C" is the unit cost of controlling the pest (Birr/plant)

"N" is the number of pests injuring the commodity unit (number of pest/plant)

"V" is the unit value of the commodity (Birr/plant)

Year I (2015/16)				Year II (2016/17)				
Treatments	Marketable yield	Marketable yield losses		Marketable yield	Marketable yield losses			
	(kg/ha)	(kg/ha)	%		(US \$/ha)	(kg/ha)		%
T1	31,384.0a	---	---	---	32,643.0a	---	---	---
T2	30,249.6ab	1,134.40	3.61	394.57	31,005.84ab	1,637.16	5.75	569.45
T3	29,115.24abc	2,268.76	7.23	789.13	29,871.48abc	2,771.52	9.2	964.01
T4	28,359.0bc	3,025.00	9.64	1,052.17	28,737.12bc	3,905.88	11.97	1,358.57
T5	27,224.64c	4,159.36	13.25	1,446.73	26,846.52c	5,796.48	17.76	2,016.17
T6	25,712.16c	#####	18.07	3,682.43	26,468.4c	6,174.60	18.92	2,147.69
T7	6,806.16d	#####	77.91	8,548.81	6,049.92d	#####	81.61	9,249.77

Table 2: Marketable yield in ton per hectare during 2015-2017 on field conditions. Note: T1=0 larval density, T2=1 larval densities, T3=2 larval densities, T4=3 larval densities, T5=4 larval densities, T6=5 larval densities, T7=Control.

Cost of production (Birr/ha)

"I" is the percentage of the commodity unit injured (% loss)/plant

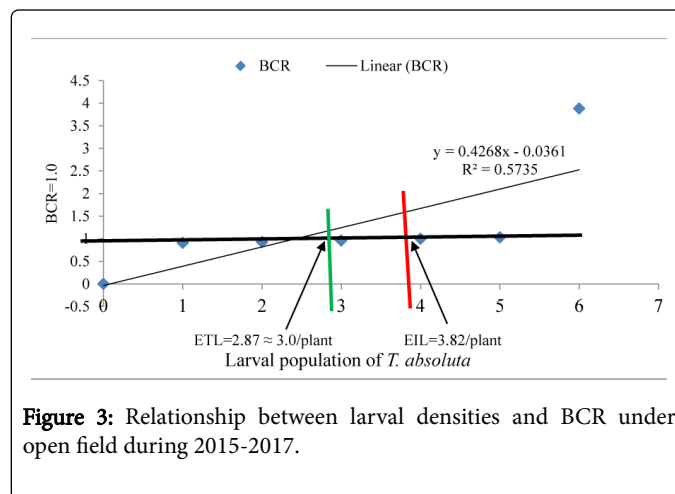


Figure 3: Relationship between larval densities and BCR under open field during 2015-2017.

From the above equations the EILs of *T. absoluta* larvae determined as three larvae during 2015-2017 (Figure 3). On the basis of means of two years, the EIL value was 3.82 larvae per plant under field conditions. Therefore, the economic threshold level was determined as 2.87 larvae per plant.

Data presented on Table 2 indicated that marketable yields per hectare were statistically significant ($P < 0.05$) different, a population density of one larva per plant caused 394.57 U.S dollar during 2015/16 which indicated 1,134.4 kg/ha yield losses. In 2016/17, one larva caused 569.45 U.S dollar which showed 1,637.16 kg/ha yield losses. The control (unsprayed) treatments were caused 8,548.81 U.S dollar during 2015/16 which showed 24,577.84 kg/ha yield losses and 9,249.77 U.S dollar lost in 2016/17 which showed that 26,593.08 kg/ha yield losses were observed. The criterion of selection of slope for economic injury level calculation was based on the worst-case scenario of yield loss per insect, i.e., the control unsprayed treatment (Table 3).

Treatments	Mean marketable yield	Mean yield loss		Value of yield loss (US\$/ha)	Mean cost of insecticide (US\$)	Mean labor charges (US\$)	Other production cost (e.g. Fertilizer, land rent, transport, cost of marketing and distribution) (US\$)	Total production cost (US\$)	Total income (US\$)	Net income (US\$)	BCR
		(kg/ha)	(%)								
T1	32,013.50	-	-	-	1,552.17	1,865.65	6,803.91	10,221.74	11,135.13	913.39	-
T2	30,627.72	1,385.78	4.68	481.23	1,004.35	1,865.65	6,803.91	9,673.91	10,653.12	979.21	0.91
T3	29,493.36	2,520.14	8.22	876.57	821.74	1,865.65	6,803.91	9,491.30	10,258.56	767.26	0.93
T4	28,548.06	3,465.44	10.81	1,205.37	821.74	1,865.65	6,803.91	9,491.30	9,929.76	438.46	0.96
T5	27,035.44	4,978.06	15.51	1,731.50	730.43	1,865.18	6,803.91	9,400.00	9,403.63	3.63	1.00
T6	26,090.28	5,923.22	18.5	2,060.25	639.13	1,865.65	6,803.91	9,308.70	9,074.88	-233.82	1.03
T7	6,428.04	25,585.46	79.76	8,899.29	0.00	1,865.65	6,803.91	8,669.57	2,235.84	-6,433.73	3.88

Table 3: Mean economic analysis of *T. absoluta* on management of tomato crop in Western Shawa of central Ethiopia on field during 2015-2017. Note: Cost of insecticides 365.22 U.S./liter Average price of tomato 0.35 U.S./kg Labor charge 3.04 U.S./day 1.00 U.S \$=23.00 Eth. Birr.

The economic threshold levels were developed from EILs, expressed as the percentage of infested plants at least three larvae/plant (Table 4). Larval survival was incorporated in the ET calculation considering the range of larval survival observed during 2015-2017.

Trt	Pest control "C"	Birr/plant	No. of <i>Tuta absoluta</i> /plant "N"	Total cost of tomato production/plant "V"	Percent of yield loss/plant "I"	EIL	BCR
T1	0.94		0	3.49	---	---	---
T2	0.61		1	3.16	4.68	4.07	0.91
T3	0.50		2	3.04	8.22	4.00	0.93
T4	0.50		3	3.04	11.38	4.29	0.96
T5	0.44		4	2.99	15.51	3.82	1.00
T6	0.39		5	2.93	18.50	3.61	1.03
T7	0.0		6 and above	2.54	79.76	---	3.88

Table 4: Economic injury level of *T. absoluta* on management of tomato crop in Western Shawa of central Ethiopia on field during 2015-2017. Note: EIL=3.82 larvae/plant. ETL=2.87 ≈ 3.0 larvae/plant.

Cost-benefit ratio

Cost of management reflects a range of actual price scenarios in current market price. Crop value considers a range of crop market price for the period of 2015-2017, including low, average, and high prices of tomato.

The crop values also are converted in U.S. dollars per Ethiopia Birr. Based on 0.03 kg of yield loss per plant with one tomato leafminer larva, conversion was done to kilograms per hectare considering 37,812 kg/ha and resulted in a yield loss mean of 1,134.36 kg/ha and untreated control was observed 0.65 kg/plant which was converted to kg per hectare 24,577.8 kg during 2015/16. In the second year (2016/17), also yield loss per plant with one larva and untreated control were 0.05 and 0.71 kg which was converted per hectare was 1,890.6 kg/ha and 26,846.52 kg/ha, respectively (Table 3).

Frequency of application

The frequency of application made sixteen times within 5 days intervals at the recommended application rates during 2015/16 and eighteen times within 5 days intervals in 2016/17 for protected (insect free) treatment. On the other hand, application times were ranged between 5-13 times during both years (Table 5).

Treatments	Frequency of application	
	(2015/16)	(2016/17)
T1	16	18
T2	10	13
T3	8	10

T4	8**	8**
T5	7*	7*
T6	5	7
T7	0	0

Table 5: Frequency of insecticide application on management of *T. absoluta* on tomato crop in Western Shawa of central Ethiopia on field during 2015-2017. Note: ** ETL * EIL.

Discussion

The experiment was conducted to uses control costs, crop value and plant-monitoring results marketable fruit loss to calculate an injury level for leaf infestation and fruit damaged. Number of larvae was indicates that initiated control prevented pests from causing economic injury while number of larval population rate above the limit indicates that the economic threshold was inadequate to prevent an increasing infestation from causing economic damage.

The EIL is the most persistent and influential element in pest management. Indeed, EIL and ETL continue to function as the primary mechanisms for making pest management decision [10]. Various workers [4,11-13] highlighted the importance of EIL and ETL in the pest management of different crop plants. According to Pedigo and Higley [14] to recapitulate the primary variables to define the EIL is not a discrete pest density, but is variable depending on control costs, the value of the production protected, production losses per pest, and the efficacy of the control. It should be noted that estimate of damage caused by pests rather than pest density is especially important for tomato leafminer, *T. absoluta*.

Currently, no any report on economic threshold level of *T. absoluta* globally. There are different damage indices and developmental stages have been used by different authors to estimate the economic injury and economic threshold level on different crops and different insect pests. For instance, Bahrami et al. and Naranjo et al.[15,16] studied the number of insects per bush for the sunn pest, *Eurygaster integriceps* (Hem: Scutelleridae) and the whitefly, *Bemisia tabaci* (Hem: Aleyrodidae), respectively, while Jemsi [17] used the density of pest on surface unit to estimation the economic injury level in the grain leaf miner *Syringopais temperatella* (Lepdoptera: Elachistidae). Reddy et al. [18] found that EIL of other lepidopteran insect, *Helicoverpa armigera* in pigeon pea was 0.78 to 0.80 larvae per plant and also Nath and Rai [19] reported EIL of gram pod borer under natural condition to be 1.77 to 2.00 larvae per m row length was determined. Furthermore, Prabhakar et al. [20] found EILs of chickpea pod borer were 0.9 and 1.23 larvae per m for unirrigated and irrigated crops, respectively. However, our method is different and easily applicable for tomato leafminer, *T. absoluta* management. We used the number of larvae per plant to simplify the observation and exact estimation of the economic injury level. This index can easily be used by farmers to estimate the intensity of damages on their tomato fruits and develop management options using their available materials.

Conclusion

The present study was also provides baseline information on the economic injury level and economic threshold level on the population

structure and growth potential of *T. absoluta*. The study on field showed that the control measures should be initiated when the *T. absoluta* population reaches 2-3 larvae per plant on field in order to prevent the population in reaching economic injury levels.

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