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Research Article

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Evaluation of Bio-Pesticides on Integrated Management of Tomato Leafminer, *Tuta absoluta* (Meyrick) (Gelechiidae: Lepidoptera) on Tomato Crops in Western Shewa of Central Ethiopia

Tadele Shiberu* **and Emana Getu**

Department of Zoological Sciences, College of Natural and Computational Sciences, Addis Ababa University, Ethiopia

***Corresponding author:** Tadele Shiberu, Department of Zoological Sciences, College of Natural and Computational Sciences, Addis Ababa University, Ethiopia, Tel: +251-111-239 472; Fax:+251-111-239 469; E-mail: tshiberu@yahoo.com

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Abstract

The tomato leaf miner *Tuta absoluta* (Meyrick) became a serious pest to tomato crop in Ethiopia since 2012, where it causes a significant damage to the crop. Field studies were conducted during 2015-2017 to determine the effectiveness of different bio-pesticides on management of *T. absoluta* and the impact of bio-pesticides on the occurrence of this pest on tomato. All tested bio-pesticides caused significant larval mortality, particularly the extract of *Azadirachta indica* and *Allium sativum*; and entomopathogenic fungus of *Beauveria bassiana* were gave 74.26%, 71.82% and 74.14%, respectively. The lowest larval mortality was recorded in mixture of Prosuler Oxymatrin and Emamectin Benzoate 50.66%. However, all bio-pesticides were highly significant ($P<0.01$) different as compared with the standard check (Coragen 200 SC) 95.83% and untreated control 2.09% within 10th days of application. The maximum mean marketable yields were obtained from Tetraniliprole (Vayego 200 SC) and Coragen 200 SC in all three districts followed by *A. indica*. The lowest marketable yield was observed by Prosuler Oxymatrin and Emamectin Benzoate (15.69 ton/ha). The minimum leaves infestation and fruits damaged were recorded. Hence, leave and fruit infestation was minimized and marketable yield increased to some extent. Therefore, the tested bio-pesticides were effective and economically viable to utilize as a component in integrated pest management to control *T. absoluta*.

Keywords: Biopesticide; Botanicals; Entomopathogenic; Insecticides; *Lycopersicon esculentum; Tuta absoluta*

Introduction

Tomato (*Lycopersicon esculentum* Mill.) belonging to Solanaceae family is an important and remunerative vegetable crop grown around the world for fresh market and processing. It is widely cultivated in tropical, sub-tropical and temperate climates and thus ranks third in terms of world vegetables production. Global tomato production is currently around 130 million tons, of which 88 million are destined for the fresh market and 42 million are processed [1]. The leading tomato producing countries are China, India, Nigeria, Turkey, Egypt and United State. They account for 70% of global production [1,2]. It is one of the economically important vegetable crops with a total area and production of 5, 023, 810 ha and 170, 750, 767 tons in 2014 [1].

In Ethiopia, due to a favourable climate conditions tomato production and the annual production of the crop is 30, 700 tons of tomato fruits from about 5, 026 ha of land [1,2]. Tomato is a seasonal plant which is one of the most economically important and widely grown vegetable crops in Ethiopia both in the rainy and dry seasons for their fruits by smallholder farmers and commercial state and private farms. It is also a source of basic raw materials required for fresh consumption and local processing industry for the production of processed tomato like tomato paste and tomato juice among others [3].

Tomato production faces many problems from several factors which lead to significant yield loss such as seasonal weather, temperature, humidity, diseases and insect pests. There are several insect species feed on tomato [4] for instance, whitefly, Africa fruit bollworm, tomato fruit worm, leafminer, leafhopper, aphid, mites and thrips. The diversity of worldwide biotic communities has greatly changed in recent years due to the collapse of natural barriers to wild species movements mainly in relation to human activities [5]. Among the newly introduced insect species, some can become invasive, with subsequent significant economic impacts. Among the newly introduced insect pests tomato leaf miner, *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) is a serious pest of tomato and other Solanaceous crops in many areas of the world causing severe damage and yield loss [6-8].

In Ethiopia, the occurrence of *T. absoluta* was confirmed under greenhouse and open field in Eastern Ethiopia [9,10]. Similarly, [11] reported that it was entered into Ethiopia in 2012 via the northern part of the country, likely from Yemen, a country severely affected by infestations of tomato leaf miner and Sudan via Humera and distributed to northern Ethiopia. Even though studies of *T. absoluta* distribution and its impact in Ethiopia are in initial phase, it seems that first recorded in potential tomato growing areas of rift valley and central parts of Ethiopia. The introduction of non-indigenous species to the new biotic community of the world has brought several problems in different places in the world [12]. Among the newly introduced species in Ethiopia that are of significant economic importance is *T. absoluta* [8,11,13]. Due to lack of natural barriers, porous borders and lack of quarantine regulation implementation in Ethiopia, the invasive species can move from one ecological community to the other through wind and human activities.

The primary *T. absoluta* management strategy in most native home, South America, or invaded European and African countries, is chemical control [14]. However, pesticides are only partially successful because of the general endophytic behaviour of the larval instars [15]. The resistance development in this pest to chemicals had been reported [16,17]. The prophylactic tools may be effective and eco-friendly way to control this invasive pest [18]. There is a real need to improve crop protection against *T. absoluta* and in the meanwhile reducing the use of synthetic insecticidal compounds [19]. Therefore, this study was intended to evaluate the effect of different bio-pesticides against *T. absoluta* larvae on tomato plants under farmers' field conditions.

Materials and Methods

Description of the study area

The field experiment was carried out on farmers' field at three different districts of West Shewa Zone, Oromia Regional state, Ethiopia, such as Ambo, Dandi and Toke Kutaye districts. Ambo is at geographical coordinate of 8 °59'N latitude and 37.85°E longitude with an altitude of 2100 meter above sea level. Toke Kutaye districts is located at 126 km west of Addis Ababa having an altitude of 1990 meter above sea level, latitude of 08 ° 59' 01.1' North and longitude of 37° 46' 27.6' East. The average annual rainfall is 1028.7 mm and maximum and minimum temperatures of the area 29.6°C and 11.8°C, respectively.

Experimental materials and layout

Tomato cultivar known as "Koshoro" was brought from Melkasa Agricultural Research Center. The seeds were drilled in flat seed bed having 2 m length and 1.2 m width (2.4 m^2) for raising seedlings for the experiment. Nine selected treatments were considered for the experiments such as *Allium sativum, Nicotiana* sp., *Cymbopogon citrates*, *Azadirachta indica*, a mixture of Prosuler Oxymatrin (Levo 2.4SL^{TM}) and Emamectin Benzoate (Prove 1.9 E.C^{TM}), *Beauveria bassiana*, *Metarhizium anisopliae*, Tetraniliprole (Vayego 200 SC), Chlorantraniliprole (Coragen 200 SC) as a standard check and untreated control was also considered for comparision. The field study was laid out in a Randomized Complete Block Design with three replications. Plant to plant and row-to-row distances were kept at 40 cm and 80 cm, respectively. The experimental plot was consisted of an area 4 m long and 3 m wide, with a total area of 12 m^2 and a working area of 9.6 m^2/plot comprising the central row. All agronomic practices were conducted as recommended (Table 1).

a. Medicinal plants					
Common name	**Amharic name**	**Scientific name**	**Family**	**Used part (s)**	
Tobacco	Timbaho	*Nicotiana sp*	Solanaceae	Leaf and stalk	
Lemon grass	Keysar	*Cymbopogon citratus*	Gramineae	Leaf	
Garlic	Nich shinkurti	*Allium sativum*	Lilliaceae	Cloves	
Neem	Yekinin zaf	*Azadirachta indica*	Meliaceae	Seed	
b. Entomopathogenic fungi					
Isolate Code	**Host**	**Place of collection**	**Genera**	**Source**	**Germination (%)**
PPRC-2	*Pachnoda interupta*	Ashan, Ethiopia	*Metarhizium*	PPRC, Ambo	79
PPRC-56	*Pachnoda interupta*	Sefi beret, Ethiopia	*Beauveria*	PPRC, Ambo	93
c. Insecticides					
Common name	**Trade name**	**Rate/ha**			
Chlorantraniliprole	Coragen 200 SC	250ml			
Tetraniliprole	Vayego 200 SC	600 ml			

Table 1: List of some crude extracts of medicinal plants (a), Entomopathogenic fungi (b) and insecticide (c) used against *T. absoluta* on open field conditions.

Preparation of materials

Botanical preparation: All tested botanicals were collected and simultaneously separated from any infestation of disease and insect pest and then washed and cut into small pieces. *A. sativum* plants were obtained from a local market in Ambo, Ethiopia and were used as fresh extract. *A. sativum* extraction was prepared according to the method described by [20] using the following items: 250 g of garlic fresh bulbs were shopped and strained in grinder, then the shopped bulbs were soaked in one litre of distilled water for one hour. *C. citratus* extraction was prepared according to [21] as follow: Dried leaves of lemongrass were powdered and strained. Fifty grams of powdered dried leaves were soaked in two litres of distilled water for six hours. All the botanicals were ground and mixed were strained and filtered through cheese cloth and were considered as stock solution. The stalk solution mixed with water at 10% concentration level (v/v) i.e 10 ml of extracts in 100 ml of water.

Fungus culture: Isolates of *Metarhizium anisopliae* and *Beauveria bassiana* were obtained from Ambo Plant protection research center. These entomopathogenic fungi was cultured on potato dextrose agar medium containing 20 g glucose, 20 g starch, 20 g agar, and 1000 ml of distilled water in test tubes. The test tubes containing PDA medium was autoclaved at 121°C for 15-20 minutes and was incubated at 27 ±

1°C, 80 ± 5% relative humidity and photophase of 12 hours for 15 days. The relative humidity was measured using Huger Hygrometer. The conidia were harvested by scraping the surface of 14-15 days old culture gently with inoculation needle. The conidia were suspended in distilled water containing 0.1% Tween-80. The mixture was stirred with a magnetic shaker for ten minutes. The hyphal debris was removed by filtering the mixture through fine mesh sieve. The conidial concentration of final suspension was determined by direct count using Haemocytometer. Serial dilutions were prepared in distilled water and were preserved at 5°C until use.

Viability Test: Conidial viability was assessed according to [22]. From previous laboratory and glasshouse experiment both agents are effective at 2.5×10^9 conidia ml^{-1}. The conidia were stained with lacto-phenol cotton blue and germination was observed under microscope. In all tested isolates of entomopathogenic fungi, spore germination rates were more than 80%.

Data collection: The field experiment was scouted every week for the signs and symptoms of tomato damage and occurrence until leaves infested by *T. absoluta*. Before treatment application pre-spray counts were made and then treatment application follows. The treatments were applied at vegetative, flowering and fruit setting stages of the crop.

After treatment application five plants were randomly selected in each treatment and data on *T. absoluta* larvae both live and dead (per plant) was observed under microscope at 3, 5, 7 and 10 days intervals. After three days of post spray all leaves were counted during pre-spray would collected and brought to laboratory. The dead larvae were removed and live larvae were observed under microscope until 10 days of post spray. Larvae were considered as dead when they were not able to move back to the ventral position after being placed on their dorsum. Finally, the fruit yield per hectare was recorded.

Data analysis

Obtained data were transformed using Arcsine transformed and analysis of variance was computed using SAS program version 9.1 [23]. The mean percent mortality was corrected using Abbott's formula [24] and Efficacy analysis was done based on data transformation to Arcsine $\sqrt{x+0.5}$ when necessary according to [25].

$$CM(\%) = \frac{[T(\%) - C(\%)]}{[100 - C(\%)]} X100$$

Where, CM (%): Corrected mortality

T: Mortality in treated insects

C: Mortality in untreated insects.

Results

Effect of bio-pesticides on larvae of *T. absoluta*

Effect of bio-pesticides on larvae of *T. absoluta* showed that in all districts, significant (P<0.01) differences were found among the treatments (Table 2). After 3 days of treatment application, about 0-96.19% mean larval percent mortalities were observed due to application of different bio-pesticides when compared to untreated control and standard check 2.09% and 94.74%, respectively. The highest percent mortality was recorded in Vayego 200 SC 96.19% and the lowest percent mortality was observed in *Nicotiana* sp. 39.35 but both entomopathogenic fungi (*B. bassiana* and *M. anisopliae*) were no effect on *T. absoluta* within 3 days of treatment application, because of the establishment of fungi in the larvae of insect pests take some days.

Treatments	Locations			
	Ambo	Dandi	Toke kutaye	Mean
Allium sativum	50.86^{bc}	57.57^{bcd}	43.10^{c}	50.51^{b}
Nicotiana sp.,	33.33^{bc}	43.60^{d}	41.11^{c}	39.35^{b}
Cymbopogon citratus	59.26^{b}	66.67^{b}	38.91	54.55^{b}
Azadirachta indica	27.61^{c}	61.24^{bc}	42.26^{c}	43.70^{b}
Tetraniliprole (Vayego 200 SC)	96.78^{a}	93.38^{a}	98.42^{a}	96.19^{a}
Beauveria bassiana	0.00^{d}	0.00^{e}	0.00^{d}	0.00^{c}
Metarhizium anisopliae	0.00^{d}	0.00^{e}	0.00^{d}	0.00^{c}
Coragen 200 SC	91.41^{a}	96.97^{a}	95.83^{a}	94.74^{a}
Control	6.27^{d}	0.00^{e}	0.00^{d}	2.09^{c}
LSD at 0.01	16.11	8.95	12.77	13.53
CV (%)	20.47	20.29	16.57	19.11
SE ±	6.76	3.75	5.35	5.67

Note: Means with the same letter (s) in rows are not significantly different for each other. All treatment effects were highly significant at p<0.01 (DMRT)

Table 2: Mean efficacy percentage of bio-pesticides against *T. absoluta* after 3 days of treatment application on field conditions.

Treatments	Locations			
	Ambo	Dandi	Toke kutaye	Mean
Allium sativum	62.48^{d}	69.80^{b}	48.90^{bc}	60.39^{b}
Nicotiana sp.,	41.67^{b}	60.12^{b}	41.10^{bc}	47.63^{bc}
Cymbopogon citratus	65.74^{b}	60.32^{b}	49.14^{bc}	58.40^{b}
Azadirachta indica	52.31^{b}	59.02^{bc}	52.80^{b}	54.71^{b}
Tetraniliprole (Vayego 200 SC)	96.78^{a}	93.38^{a}	98.42^{a}	96.19^{a}
Beauveria bassiana	37.29^{b}	13.35^{de}	29.17^{cd}	26.60^{d}
Metarhizium anisopliae	45.19^{b}	30.16^{cd}	16.31^{d}	29.45^{cd}
Coragen 200 SC	91.41^{a}	96.97^{a}	95.83^{a}	94.74^{a}
Control	6.27^{c}	6.27^{e}	0.00^{d}	4.18^{e}
LSD at 0.01	19.97	16.36	12.77	13.59
CV (%)	18.66	15.4	13.32	15.79
SE ±	8.37	6.86	6.38	7.2

Note: Means with the same letter (s) in rows are not significantly different for each other. All treatment effects were highly significant at p<0.01 (DMRT)

Table 3: Mean efficacy percentage of bio-pesticides against *T. absoluta* after 5 days of treatment application on field conditions.

Treatments	Locations			
	Ambo	Dandi	Toke kutaye	Mean
Allium sativum	68.29^{b}	69.10^{bc}	70.45^{b}	69.28^{b}
Nicotiana sp.,	46.22^{bc}	50.80^{cd}	51.85^{b}	49.65^{bc}
Cymbopogon citrates	65.66^{bc}	77.3^{b}	64.71^{b}	69.22^{b}
Azadirachta indica	69.69^{b}	60.10^{bcd}	71.29^{b}	67.03^{c}
Tetraniliprole (Vayego 200 SC)	96.78^{a}	93.38^{a}	98.42^{a}	96.19^{a}
Beauveria bassiana	47.75^{bc}	54.13^{cd}	67.04^{b}	56.31^{bc}
Metarhizium anisopliae	55.71^{bc}	39.68^{d}	58.40^{b}	51.26^{bc}
Coragen 200 SC	94.19^{a}	93.64^{a}	95.83^{a}	94.55^{a}
Control	9.97^{d}	6.23^{e}	0.00^{c}	5.40^{d}
LSD at 0.01	21.44	13.35	11.67	12.22
CV (%)	18.69	20.65	19.78	19.71
SE ±	6.29	5.60	4.89	5.59

Note: Means with the same letter (s) in rows are not significantly different for each other. All treatment effects were highly significant at p<0.01 (DMRT)

Table 4: Mean efficacy percentage of bio-pesticides against *T. absoluta* after 7 days of treatment application on field conditions.

Treatments	Locations			
	Ambo	Dandi	Toke kutaye	Mean
Allium sativum	68.28^{b}	76.40^{b}	72.78^{bcd}	72.49^{b}
Nicotiana sp.,	46.29^{bc}	49.90^{de}	51.85^{e}	49.35^{c}
Cymbopogon citrates	65.57^{bc}	77.30^{b}	64.71^{bcde}	69.19^{b}
Azadirachta indica	72.39^{b}	74.03^{bc}	76.07^{bc}	74.26^{b}
Tetraniliprole (Vayego 200 SC)	96.78^{a}	93.38^{a}	98.42^{a}	96.19^{a}
Beauveria bassiana	78.37^{b}	65.66^{bcd}	78.40^{b}	74.14^{b}
Metarhizium anisopliae	64.76^{bc}	54.76^{cde}	58.40^{cde}	59.31^{bc}
Coragen 200 SC	94.19^{a}	96.97^{a}	95.83^{a}	95.66^{a}
Control	9.97^{d}	6.23^{f}	0.00^{d}	5.40^{d}
LSD at 0.01	20.04	12.32	12.02	14.79
CV (%)	18.83	19.94	19.81	19.53
SE ±	8.99	5.16	5.04	19.53

Note: Means with the same letter (s) in rows are not significantly different for each other. All treatment effects were highly significant at p<0.01 (DMRT)

Table 5: Mean efficacy percentage of bio-pesticides against *T. absoluta* after 10 days of treatment application on field conditions.

Data in (Tables 3-5) showed that at the 5th day treatment application of the experiment, mortality percentage of *T. absoluta* on tomato fruit were better than the 3rd day in all treatment plots and in all locations except the standard check (Coragen 200 SC) and Vayego 200 SC they gave high percent mortality in all districts. The other treatments percent mortality gradually, increased from 0% to 74.26% after 10 days from the third day application of the experiment. Meanwhile, in the plots receiving bio or chemical insecticides experienced a marked gradual increased in percent mortality and decreased the infestation level of *T. absoluta*. This effect was most evident post spraying by *A. sativum* 76.40, and *C. citrates* 77.30, both in Dandi and Ambo districts, whereas *A. indica* 76.07 in Toke kutaye district. The least toxic effect was exhibited by *Nicotiana* sp. 46.29, 49.90 and 51.85 in Ambo, Dandi and Toke kutaye districts, respectively.

The chemical insecticides Tetraniliprole (Vayego 200 SC) showed very low toxic effect on *T. absoluta* following 10 days treatment applications, and percent mortality was low in all locations as compared with other treatments but highly significant (P<0.01) different from untreated control. In general, after 5th, 7th and 10th day of treatment application the results of all treatments proved better percent mortality on larvae of *T. absoluta* as compared with 3rd day of application (Table 5).

Effect of bio-pesticides on leaf and fruit of tomato infestation

In Ambo district, data recorded on number of leave infested and fruits bored per plant were presented in Table (6). All treatments were significantly reduced *T. absoluta* leaf infestation compared to untreated control. Plants treated with *A. sativum, C. citrates, A. indica, B. bassiana* and Coragen 200 SC were recorded the lowest infestation of leaves by *T. absoluta* followed by *M. anisopliae*. On the other hand, the effect of *A. indica* (1.33), *C. citrates* (2.33), *B. bassiana* (2.33), Vayego 200 SC (1.33) and Coragen 200 SC (1.33) on tunneled fruits per plant at the same district and not significantly differed to each other but highly significant (P<0.01) different from untreated control (12.33)/ plant. The highest leave infestation was recorded in untreated control followed by a mixture of Prosuler Oxymatrin and Emamectin Benzoate (11.33) and *Nicotiana* sp. (8.0)/plant were recorded.

In Dandi district, infestation of leaves were observed on standard check (Coragen 200 SC) (4.33)/plant the lowest infestation and followed by *C. citrates* (10.67), *B. bassiana* (11.0), *A. indica* (11.67) and *A. sativum* (13.67)/plant were recorded. The standard check was significant (P<0.05) different from other treatments. Similarly, the untreated control also highly significant (P<0.01) different from all treatments and recorded the highest leave infestation (42.67)/plant (Table 5). The effects of bio-pesticides on fruit of tomato against *T. absoluta* were evaluated. It was showed that most of the treatments gave low fruit tunneled, among of these Vayego 200 SC and Coragen 200 SC (0.0), *B. bassiana* (0.33) *A. sativum* (1.33), *C. citrates* (1.67), and *A. indica* (1.67) per plant. Most of the treatments reduced tunneled tomato fruits significantly compared to untreated control. Similar results were observed in Toke kutaye district (Table 6).

In all districts, treatments were found significantly superior over the control. Leaf infestation and fruits bored by of tomato leaf miner, *T. absoluta* was reduced after treatment application. Results proved a significant P<0.01) difference in infestation level of *T. absoluta* as affected by the different control treatments under field conditions. The differences can be attributed to different modes of action of the products and also the number of days after treatment application. The results showed that *A. sativum*, *C. citratus*, *A. indica*, and *B. bassiana* were reduced number of leaf infested and fruit tunneled per plants in all districts (Table 6).

Treatments	**Locations**					
	Ambo		**Dandi**		**Toke kutaye**	
	Leaf infested	Fruit bored/plant	Leaf infested	Fruit bored/plant	Leaf infested	Fruit bored/plant
Allium sativum	9.33^{d}	1.67^{b}	13.67^{cd}	1.33^{d}	11.0^{de}	2.33^{c}
Nicotiana sp.,	23.67^{b}	8.0^{b}	22.67^{b}	7.33^{b}	18.67^{bc}	6.33^{b}
Cymbopogon citratus	8.0^{d}	2.33^{c}	10.67^{d}	1.67^{d}	15.0^{cd}	2.33^{c}
Azadirachta indica	8.0^{d}	1.33^{c}	11.67^{d}	1.67^{d}	11.33^{d}	1.33^{c}
Tetraniliprole (Vayego SC 200)	3.0^{d}	1.33^{c}	3.67^{e}	1.0^{d}	2.67^{e}	1.0^{c}
Beauveria bassiana	8.0^{d}	2.33^{c}	11.0^{d}	0.33^{d}	10.33^{de}	0.67^{c}
Metarhizium anisopliae	15.0^{c}	6.0^{b}	17.33^{c}	4.67^{c}	15.33^{bcd}	5.67^{b}
Coragen 200 SC	6.33^{d}	1.33^{c}	4.33^{e}	0.0^{d}	4.67^{e}	0.67^{c}
Control	49.0^{a}	12.33^{a}	42.67^{a}	18.0^{a}	41.33^{a}	9.0^{a}
LSD at 0.01	4.84	2.66	4.25	2.56	6.38	2.22
CV (%)	12.32	21.52	10.58	22.47	16.13	24.46
SE ±	2.03	1.12	1.78	1.07	2.68	0.93
Note: Means with the same letter (s) in rows are not significantly different for each other. All treatment effects were highly significant at p<0.01 (DMRT)						

Table 6: Mean infestation of leaf and fruit per plant on different Districts of West Shewa of Central Ethiopia.

Treatments	**Locations**			Mean Marketable yield/ha in tons
	Ambo	**Dandi**	**Toke kutaye**	
	Marketable yield/ha	Marketable yield/ha	Marketable yield/ha	
Allium sativum	23.63^{b}	26.8^{ab}	19.30^{bc}	22.30
Nicotiana sp.,	12.83^{d}	15.33^{e}	11.61^{e}	13.26
Cymbopogon citratus	19.72^{c}	24.19^{abc}	17.83^{cd}	20.58
Azadirachta indica	25.37^{ab}	25.00^{abc}	20.37^{abc}	23.58
Tetraniliprole (Vayego 200 SC)	29.69^{a}	28.05^{a}	25.33^{a}	26.69
Beauveria bassiana	25.17^{ab}	27.53^{ab}	21.62^{ab}	24.77
Metarhizium anisopliae	19.25^{c}	21.17^{cd}	15.70^{d}	18.71
Coragen 200 SC	28.01^{a}	29.03^{a}	23.53^{a}	26.86
Control	8.43^{e}	5.60^{f}	4.62^{f}	6.22
LSD at 0.01	3.37	4.38	3.27	
CV (%)	7.16	8.53	8.41	
SE ±	1.41	1.84	1.37	
Note: Means with the same letter (s) in rows are not significantly different for each other. All treatment effects were highly significant at p<0.01 (DMRT)				

Table 7: Mean marketable yield per hectare in tons on different locations of West Shewa, Central Ethiopia.

Effect of bio-pesticides on yield of tomato

Evaluation of different bio-pesticides against *T. absoluta* under three different districts of West Shewa on effect tomato fruit yields. No significant (P>0.05) differences were recorded among the treatments of *B. bassiana*, *A. indica* and the standard check (Coragen 200 SC) depicted on (Table 7).

The highest mean yield at all districts obtained in treatment of standard check, Coragen 200 SC (26.86 ton/ha) followed by *B. bassiana* (24.77 ton/ha) and *A. indica* (23.58 ton/ha). The minimum yields were recorded in untreated control (6.26 ton/ha) followed by *Nicotiana* sp. (13.26 ton/ha). Considering the mean marketable fruit yield production, the fruits that were highly damaged by *T. absoluta*, for each treatment (Table 5), the maximum and minimum production were obtained from plants treated with *A. sativum* (23.63 ton/ha) and *Nicotiana* sp. (12.83 ton/ha) in Ambo district, *B. bassiana* (27.53 ton/ha) and *Nicotiana* sp. (15.33 ton/ha) in Dandi district and similar results were observed in Toke kutaye district, respectively.

Yield loss estimation: Highly significant (P<0.01) differences were observed from untreated check in all Districts in terms of yield losses. Low yield losses recorded in the plots treated with *B. bassiana*, between 6.87% to 10.08% followed by *A. indica* 7.33 to 13.13% yield losses at harvested time. The maximum yield losses were recorded from plots treated with *Nicotiana* sp (44.01, 42.32 and 37.88%) in Ambo, Dandi and Toke kutaye Districts, respectively. In the control plots the yield losses of the untreated plots were between 59.16 to 70.12% in all three Districts of West Shawa of Central Ethiopia (Table 8). Therefore, yield losses depend on infestation level of *T. absoluta*.

Treatments	Locations					
	Ambo		Dandi		Toke kutaye	
	Wt of tomatoes (tons/ha)	Yield Loss in (%)	Wt of tomatoes (tons/ha)	Yield Loss in (%)	Wt of tomatoes (tons/ha)	Yield Loss in (%)
Allium sativum	27.29^{be}	21.40	31.11d	8.26	24.95^{b}	12.09
Nicotiana sp.,	19.44^{de}	44.01	19.56^{d}	42.32	17.63^{e}	37.88
Cymbopogon citratus	23.92^{cd}	31.11	28.36^{bc}	16.37	23.36^{bc}	17.69
Azadirachta indica	30.16^{abc}	13.13	30.46^{ab}	10.17	26.23^{ab}	7.33
Tetraniliprole (Vayego 200 SC)	35.31^{cd}	---	36.22^{c}	---	28.62^{de}	---
Beauveria bassiana	31.22^{ab}	10.08	31.01^{ab}	8.55	26.43^{ab}	6.87
Metarhizium anisopliae	26.64^{bc}	23.28	27.22^{bc}	19.73	21.47^{cd}	24.35
Coragen 200 SC	34.72^{a}	---	33.91^{a}	---	28.38^{a}	---
Control	14.18^{e}	59.16	11.64^{e}	65.67	8.48^{f}	70.12
LSD at 0.01	6.12		4.22		2.92	
CV (%)	10.77		6.64		5.58	
SE ±	2.78		1.77		1.23	
Note: Means with the same letter (s) in rows are not significantly different for each other. All treatment effects were highly significant at p<0.01 (DMRT)						

Table 8: Yield losses of tomato fruits after treatment application against *T. absoluta* during 2015/2016 in three different locations of West Shewa, Oromia Regional State, Ethiopia.

Discussion

Limited information is available regarding the efficacy of bio-pesticides against *T. absoluta*. However, the use of traditional botanical pesticides during the past decades and their efficacy against different pests has led to their wide acceptance throughout the world. Researchers have focused on the use of botanical extracts, oils and plant powders, which are cheap, of short persistence and of low mammalian toxicity. A number of references [21,26] indicated that, many of these plant materials show a broad spectrum of activity against insect pests, such as lethal, antifeedant, repellent and growth regulatory effects.

Our studies also revealed that after 3 days of treatment application *B. bassiana* and *M. anisopliae* indicated no effect on the larvae of *T. absoluta*. It can be supposed that, the establishment of fungi on the larvae of insect pests take some days. The results of the present experiments are quite similar to that of [27], who applied Neem seed extract against larvae of *T. absoluta*. The result of the experiments showed high percent mortalities of entomopathogenic fungi against *T. absoluta* larvae up to 78.40% obtained after 10 days of treatment application on different locations. Many findings indicated effective larval control of *T. absoluta* with different botanical extracts were recorded in different countries. It was contrast with the work of [27], he was reported that application of Neem seed extract against larvae of *T. absoluta* resulted 84%-100% mortality after 4 days while our findings proved that Neem seed extracts at 10% concentration showed that 52.31 to 59.02 percent mortality after 5 days of application. However, it was increased after 7 to 10 days of treatment application 65.66 to 78.40 percent mortality on different locations. Coragen 200 SC exhibit the good mode of action, this explains their similar mean reduction in *T. absoluta* infestation [28]. This finding was agree with the work of [29], they were suggested that *B. bassiana* and *M. anisopliae* has a potential effect on larvae of *T. absoluta*.

This finding was agreed with the work of [30] control of *Tuta absoluta* by three microbial control agents including *B. bassiana* which increase the yield of tomato fruit [31] reported that garlic extracts and other naturally derived plant chemicals are becoming increasingly subject to official recognition in regard to their pesticidal activity. Our findings also confirmed plant extracts including garlic were prepared and tomato plants infested with leaf miner were sprayed three times at vegetative, flowering and fruit setting, all treatments reduced population density of tomato leaf miner significantly. The highest reduction was recorded by *A. sativum* extract followed by *C. citratus* extract and also, garlic extract increased the yield of tomato significantly.

Effective management option in conjunction with integrated pest management (IPM) is vital to global crop protection, sustainable agriculture and improved public health [32]. Both yield and fruit quality can be significantly reduced by the direct feeding of *T. absoluta* and secondary pathogens that may enter through the wounds made by the insect. Similar results obtained by [33] who controlled the pinworm by bio-insecticides. Several Researchers reported, if no control measures are taken, then the pest can reduce tomato yield and fruit quality up to 80-100% yield losses by attacking leaves, flowers, stems and especially fruits [16,34,35]. But this field experiments in three different districts indicated that 59.16-70.12% yield losses were recorded.

Conclusion and Recommendation

It could be concluded that the effect of bio-pesticide application were provided for on treated plants. Concerning the most effectiveness of treatments, it was found that the lower infestation level the higher marketable yield and less yield percent loss. Thus our field experiment suggested that Vayego 200 SC, *B. bassiana*, *A. indica*, *A. sativum* and *C. citratus* has a potential effect on larvae of *T. absoluta* under field conditions. Considering, the high risks of chemical insecticides on human being, mammals and birds as well as in the environment bio-pesticides are a cheap, valuable, safe and environmentally friendly alternative insect pest management. There are indications that producers consider available information on management of *T. absoluta* when choosing different control strategies. The newly tested bio-pesticides and report of effectiveness efforts, in addition to the synthetic chemical insecticides. Hence, more researches with new materials in the future will constitute an asset in the field of botanicals and entomopathogenic fungi on different climatic conditions.

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