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Evaluation of Botanical Insecticides on Management of *Tuta absoluta* (Lepidoptera: Gelechiidae) on Tomato at Ambo, Ethiopia

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ABSTRACT

Both as a food supply and a medical treatment, tomatoes are extremely valuable. One of the most damaging pests to tomatoes in the world is Tuta absoluta. T. absoluta larvae (10 larvae/Petri dish) were sprayed with botanical crude extracts as part of scientific experiments. Post-spray counts were done at 24, 48, 72, 96, and 120 hr after exposure to botanical extracts under both conditions. The results showed that Carica papaya, Moringa olifera, Zingiber officinale, and Capsicum sp. at concentrations of 150, 100, 100, and 75 g/L killed 74.44%, 74.45%, 75.55%, and 85.55% of T. absoluta larvae, respectively. Under glasshouse conditions, minimum & maximum mortality percentages were recorded in three rounds of spray treatment by Capsicum sp. (26.77-87.86%), Zingiber officinale (23.30-84.07%), Moringa oleifera (20.70-79.83%), and the last mortality was recorded by Carica papaya (19.02-72.19%). The Capsicum sp. produced the largest output, whereas the control plants produced the lowest mean tomato yield (250.50 gm/plant). 99.55% of the yield losses were seen in untreated plants, whereas the aggregate percentages of yield losses from treated plants were 3.61-26.56. It can be suggested that more field studies concentrate on the effects of toxicity on people, soil, and the environment, as well as the efficacy of botanical products at varying rates. Researchers and farmers in the West Shoa Zone require it, along with additional considerations as part of integrated pest control methods to combat the targeted insect pests.

Keywords: *Botanicals, Efficacy, Insecticide, Mortality, Tomato, Tuta absoluta*

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INTRODUCTION

Botanically known as the Solanaceae family, the tomato (Solanum lycopersicum L.) is one of the most significant and widely consumed vegetable crops in the world for both fresh eating as well as grinding (Abdussamee *et al*., 2014; Kaur *et al*., 2014; Mehraj *et al*., 2014; Akbari, 2022; Levochkina *et al*., 2024). Because of the climate's conduciveness to tomato cultivation, Ethiopia produces 30,700 tons of tomato fruits annually from around 5,026 hectares of land, making it one of the country's most commercially significant vegetable crops (FAO, 2015; Fact Fish, 2016; Asar *et al*., 2023). The world's climate variations are alarmingly growing, which increases the likelihood that various invasive insect pests may develop (Robinet & Roques, 2010; Abbas *et al*., 2023). Tomato production can range from 15.9 to 46.3 tons/ha (Central Statistics Agency, 2013; Imanova 2022). However, due to a number of factors, such as insect pests, specifically tomato leaf miners, tomato fruit worms, whiteflies, leafhoppers, aphids, mites, and thrips, the average amount of tomatoes produced per hectare is estimated to be 7.67 tons (Assaf *et al*., 2013; El-Arnaouty *et al*., 2014; Bawin *et al*., 2015; Tonnang *et al*., 2015; Daniel & Bajarang, 2017; Dereyko *et al*., 2023; Ha *et al*., 2024).

One of the most damaging pests to tomatoes globally is the tomato leaf miner, Tuta absoluta (Desneux, 2010; Hoang *et al*., 2022; Çelik *et al*., 2024). Because of its ability to grow swiftly in tomato plants and spread fast to other locations, it is regarded as a typical invasive species that can cause damage that is economically significant (Desneux, 2010; Alexander *et al*., 2024). The bug has seriously harmed tomatoes in regions it has infiltrated since it was first discovered. Most likely from Sudan or Yemen, the pest entered Ethiopia in 2012 (Gashewbaza & Abiy, 2013; Goftishu *et al*., 2014; Shiberu & Getu, 2017; Ranganadhareddy *et al*., 2022).

Nearby Yemen, where serious tomato leafminer infestations have been documented (Gray *et al*., 2013; Karpov *et al*., 2023), and the northern region of Ethiopia, which borders Sudan via Humera (Retta & Berhe, 2015; Konaré *et al*., 2024), were thought to be potential entry points for T. absoluta. Invasive species can spread from one ecological group to another by wind and human activity because Ethiopia lacks natural barriers, permeable borders, and the application of quarantine regulations. After spreading to sections of Shewa and the eastern regions of Somalia and Oromia, this pest eventually made its way into the Central Rift Valley (Gashewbeza & Abiy, 2012; An *et al*., 2022).

The primary tomato-growing regions in Ethiopia were being severely overrun by T. absoluta. Given that its life cycle takes 30 to 35 days, depending on the environment, this insect has a high capacity for reproduction (Harizanova *et al*., 2009; Enwa *et al*., 2023; Barasker *et al*., 2024). Because the bug reproduces so quickly, it is more harmful and well-known in the tomato production system.

Farmers in Ethiopia's West Shoa region were shocked by their misdeeds on the plants and fruits that they were unable to sell, and they didn't realize the extent of the damage until much later, following the emergence of the lepidopterous pest (Shiberu &

Getu, 2017; Saliev *et al*., 2024). The insect's quick national distribution, mostly associated with the sale of tomato berries and nursery plants, has made it possible for it to establish itself in every region where tomato crops are grown. Among other things, the use of synthetic insecticides, the primary method of controlling insects worldwide (Senthil-Nathan, 2013; Zharashueva *et al*., 2024), frequently pollutes ecosystems, creates new and resistant pests, and destroys natural enemies (Macharia *et al*., 2009; Yalçin *et al*., 2015; Gondo *et al*., 2024). According to Adeyemi (2010) and Shrivastava and Singh (2014), there are a number of plants that include substances known as secondary metabolites that have insecticidal qualities and may thus be utilized to control a variety of insect pests.

T. absoluta infestations in Ethiopia, namely in the West Shoa Zone, ranged from 60.08% to 82.31% in the farmer's field and from 87.50% to 100% in the glasshouse (Shiberu & Getu, 2017; Abdel-Hadi & Abdel-Fattah, 2022; Molas-Tuneu *et al*., 2024). Accordingly, T. absoluta has already established itself in the Ambo district and, given the high eco-climatic index, is probably going to seriously harm tomato production economically. In order to stop T. absoluta from spreading further and to lessen the financial damages this pest causes, appropriate pest control techniques should be used in this area.

MATERIALS AND METHODS

Description of the study area

In 2021, the research was carried out on tomato plants in a glasshouse and laboratory. Tomato plants were the subject of a glasshouse experiment at Ambo University in West Shewa Zone, Oromia Regional State, Ethiopia, and a laboratory experiment at Ambo University Gudar Mamo Mezemir Campus. 110 kilometers to the west of Addis Ababa is Ambo. With an average elevation of 1380-3030 meters above sea level, the geographical points are located at 370 32' 0'' to 380 3'0'' E longitude and 80 47'0'' to 9021'0'' N latitude. The Ambo district's total cultivable area is 44,565 km^2. The district's ecosystem consists of 35.3% highland, 50% mid-altitude, and 14.7% lowland. The district's predominant soil types include clay loam (5%), black (34.37%), and red (36.25%), and grey (24.36%). Vertisol soils, which are often suitable for tomato growth, make up the experimental site. Nonetheless, it is known to be produced in Ethiopia in a variety of soil types. The lowest temperature at the trial locations is 15°C, the highest temperature is 29°C, and the yearly rainfall is 800-1000 mm.

Experimental design and materials used

The tomato cultivar "Koshoro" was seeded in November 2020 for the glasshouse study periods. The studies were set up in a Randomized Complete Design (RCD) in the laboratory with three replications and a Randomized Complete Block Design (RCBD) in the greenhouse with four replications each. The studies were performed in varied concentrations of botanical pesticides.

Treatment procedures

Laboratory experiment

Laboratory experiments were carried out on 17 January 2021 to determine the evaluation of different botanicals and synthetic insecticides with different rates under laboratory conditions. Here are four botanical insecticides: Moringa *(Moringa oleifera)* leaf powder extract, Hot pepper *(Capsicum* sp.) Fruit extract, Ginger *(Zingiber officinale*) Rhizome and papaya seed *(Carica papaya)* were used as treatments **(Table 1)**. Three concentrations of each of the four tested botanicals were prepared. Three treatment-wise releases of ten tomato leafminerlarvae were made onto each treated leaf in a 9 cm diameter by 1.5 cm high petri dish. A delicate, soft brush was used to delicately insert the T. absoluta larvae in each Petri plate, and they were then maintained in a lab setting (IRAC, 2010). The larvae were sprayed with the botanicals that had been produced. The number of deaths was recorded at 24, 48, 72, 96, and 120 hours. When larvae could not return to the ventral position after being put on their dorsum, they were deemed dead. Using the following formula, the percentage of larval mortality was determined (Alam *et al*., 2018, 2019):

$$\text{Mortality (\%)} = \frac{total\ No.of\ died\ larva\ per\ treatment}{total\ number\ of\ release\ larva\ per\ treatment} \times 100 \qquad (1)$$

Glasshouse experiment

The tomato was transplanted after 40 days on December 01, 2021, from the greenhouse. The best promising botanical insecticides with their most rates were selected for the glasshouse experiment. On January 21, 2021, botanical pesticides were sprayed on planted tomato plants at the prescribed dosages based on laboratory findings. The spraying was done three times at 10-day intervals. Data was taken before and after spraying. Mortality data were recorded at 1, 3, 5, and 7-day intervals after treatment application. Meteorological data recorded during the study period under glasshouse from January to March was a minimum temperature of 31.03^{0}C to a maximum temperature of 39.79^{0}C and 34.21 to 63.02% relative humidity. Additional field tests were conducted on the botanicals that showed the most promise. Treatment-wise, rates of larvae per plant, infected leaf percentage per plant, healthy and infested flower percentage per plant, and healthy and infested fruit percentage per plant were documented. The following formula (Alam *et al*., 2018) was used to determine the infestation percentage:

$$\text{Infested plant part (\%)} = \frac{total\ number\ of\ \ plant\ part - total\ number\ of\ healthy\ \ plant\ part}{total\ number\ of\ plant\ part} \times 100 \qquad (2)$$

$$\text{Healthy plant part (\%)} = \frac{total\ number\ of\ \ plant\ part - total\ number\ of\ infested\ plant\ part}{total\ number\ of\ plant\ part} \times 100 \qquad (3)$$

Where, plant parts in the calculation are leaves, flowers, and fruits.

Botanical collection and preparation

Hot pepper, ginger rhizome, Moringa oleifera leaf powder extract, and Carica papaya seed were all harvested as fresh fruit. They were then concurrently cleaned and sliced into little pieces after being free of illness and insect pests. The following materials were used in the botanical preparation and extraction process, which followed Stoll's (2000) methodology: After 250 g of fresh botanicals were ground and strained in a grinder, the chopped botanicals were steeped for one hour in one liter of distilled water. A stock solution was prepared by grinding, combining, straining, and filtering all of the botanicals via cheesecloth. 50, 75, and 100 milliliters of water were added to the stock solution (percent concentration levels (v/v) in 100 milliliters). T. absoluta larvae were placed in the Petri plate and sprayed with botanical crude extracts using a micropipette. Larvae received distilled water treatment as the control treatment. In order to prevent decompositions that may have caused the surviving larvae to die quickly, dead larvae were removed as soon as possible.

Table 1. List of botanical insecticides used in the experiment.

Scientific Name of Treatments	Family	Tested parts	Rate
***Capsicum* sp(L)**	Solonaceae	Green fruit extract	25g/L 50g/L 75g/L
Zingiber officinale	*Zingiberaceae*	Rhizome	50g/L 75g/L 100g/L
Moringa olifera	Moringaeae	Leaf powder extract	50g/L 75g/L 100g/L
Carica papaya	Caricaceae	seed extract	100g/L 125g/L 150g/L
Un treated control			

Data collection and measurement

In the present investigation, sample plants in each treatment were assessed according to several factors. Every week, data was gathered after each treatment's economic threshold level of two larvae per plant was attained (Shiberu & Getu, 2017). When the economic threshold level was reached, pre- and post-spray were counted.

Plant height (cm): From four replications of each experimental pot, the height of four taken plants was measured at physiological maturity from the ground to the top of the plant, and the means were recorded as plant height.

Percent mortality per treatment: To determine the larval mortality, the number of dead larvae was divided by the total number of larvae per plant, and the result was multiplied by 100.

Total number of leaves per plant: After counting the number of leaves on each pot, the average number of leaves per plant was determined.

Number of healthy leaves per plant: Healthy leaves were determined for each replication treatment by subtracting the infected leaves from the total number of plant leaves per pot.

Number of infested leaves per plant: it was recorded by counting all infected leaves from each treatment of replication, and the means were recorded as infected leaves.

Total flowers per plant: from each treatment, the replication number of flowers was recorded.

Infected flowers per plant: it was recorded by counting all infected flowers from each treatment of replication, and the means were recorded as infected flowers.

Yield of tomato: it was calculated by weighing in gm the fruit of tomato plants.

Yield loss: was calculated by $\frac{\text{potential yield} - \text{actual yield}}{\text{potential yield}} \times 100$

Statistical analysis

Using the SAS program, the findings were statistically examined using analysis of variance (ANOVA); the study of the effects of insecticides against the control and mortalities of each stage by botanicals was performed by ANOVA analysis of variance with the Newman-Keuls test with 5%.

RESULTS AND DISCUSSION

Result

Laboratory bioassay of botanicals

Table 2 shows significant differences in the mortality rates of T. absoluta larvae caused by botanical extracts after 24 hours ($F = 72.92$; $df = 12$; $p < 0.01$), 48 hours ($F = 53.79$; $df = 12$; $p < 0.01$), 72 hours ($F = 67.73$; $df = 12$; $p < 0.01$), 96 hours ($F = 274.18$; $df = 12$; $p < 0.01$), and 120 hours. The administration of Capsicum sp. at a rate of 25, 50, and 75 g/L induced percent mortality of T. absoluta of 15.55, 24.44, 34.44, 34.44, and 43.44%; 24.44, 34.44, 44.44, 45.55, and 46.67%; and 34.44, 45.55, 54.44, 75.55, and

85.55% after 24, 48, 72, 96, and 120 hours, respectively. T. absoluta death rates at 50, 75, and 100 g/L were 13.44, 15.55, 23.33, 34.44, and 44.44%; 16.66, 24.44, 32.22, 44.44, and 46.67%; and 25.55, 35.55, 42.22, 55.55, and 75.55% after 24, 48, 72, 96, and 120 hours, respectively. In a similar vein, T. absoluta larval mortality rates with administration of Moringa oleifera at rates of 50, 75, and 100 g/L were 11.11, 14.44, 16.67, 25.55, and 35.55%; 14.44, 18.89, 25.55, 34.55, and 44.44%; and 24.44, 28.89, 34.44, 55.55, and 74.55% after 24, 48, 72, 96, and 120 hours, respectively.

The fourth treatment with Caricapa paya at rates of 100, 125, and 150 g/L resulted in T. absoluta death rates of 14.44, 15.55, 24.44, 34.44, and 35.55%; 15.55, 24.44, 34.44, 44.44, and 45.55%; and 25.55, 35.55, 45.55, 55.55, and 74.44% after 24, 48, 72, 96, and 120 hours, respectively. At a rate of 75 g/L, Capsicum sp. had the greatest mortality (85.55%) of all botanicals. Overall, as the concentration of botanicals increased, so did the mortality of T. absoluta larvae over time **(Table 2)**.

Table 1. Mean percent efficacy of botanicals on *T.absoluta* at 24, 48, 72, 96, and 120 hrs after Application of treatments in the laboratory conditions.

Treatment	Rate gm/L or ml/L	Percent Mortality				
		Time in hour				
		24	28	72	96	120
Capsicum sp.	25	15.55c	24.44de	34.44c	34.44d	43.44d
	50	24.44b	34.44bc	44.44b	45.55c	46.67cd
	75	34.44a	45.55a	54.44a	75.55a	85.55a
Zingiber officinale	50	13.44cd	15.55f	23.33ef	34.44d	44.44d
	75	16.66c	24.44de	32.22cd	44.44c	46.67cd
	100	25.55b	35.55b	42.22b	55.55b	75.55a
Moringa oleifera	50	11.11d	14.44f	16.67f	25.55e	35.55d
	75	14.44cd	18.89ef	25.55de	34.55d	44.44d
	100	24.44b	28.89cd	34.44c	55.55b	74.55ab
Carica papaya	100	14.44cd	15.55f	24.44e	34.44d	35.55d
	125	15.55c	24.44de	34.44c	44.44c	45.55cd
	150	25.55b	35.55b	45.55b	55.55b	74.44ab
Control		0.00e	0.00g	0.00g	0.00f	0.00e
CV %		9.68	11.49	9.37	4.57	12.57
SE (±)		1.75	2.80	2.97	1.90	6.43
LSD at 0.01		4.00	6.41	6.79	4.33	14.70

Note: There was no discernible difference between means that had the same letter or letters in the column.
At p<0.01 (LSD), every treatment effect was extremely significant.

Glasshouse evaluation of botanical extracts

In the first round spray of 1st day post-spray treatment exposure (F = 1282.45; df = 4; p < 0.01), 3rd days (F = 4378.94; df = 4; p < 0.01), after 5th days (F = 5696.46; df = 4; p < 0.01), and after 7th day (F = 4060.44; df = 4; p < 0.01), the results indicated significant (P ≤ 0.01) differences among the botanicals in causing percent mortality to larvae among the treatments. The 1st day post-spray treatment exposure (F = 11697.3; df = 4; p < 0.01), the 3rd day (F = 7677.31; df = 4; p < 0.01), after five days (F = 12785.7; df = 4; p < 0.01), and after seven days (F = 22921.8; df = 4; p < 0.01) were the times for the 2nd round of spraying. In the third round spray of the 1st day after spray treatment exposure (F = 18131.9; df = 4; p < 0.01), 3rd day (F = 14850.0; df = 4; p < 0.01), after 5th day (F = 79126.5; df = 4; p < 0.01), and after 7th day (F = 22620.4; df = 4; p < 0.01).

The mean of total leaves was recorded after application of Capsicum sp., Zingiber officinale, Moringa oleifera, and Carica papaya and was 371.50, 351.00, 347.25, and 344.75, and 484.50, 480.25, 474.75, and 467.25 after the first and second round sprays, respectively. The control produced the fewest leaves (310.75 and 377.75, respectively) **(Tables 3 and 4)**.

The mean of healthy leaves reported after application of Capsicum sp., Zingiber officinale, Moringa oleifera, and Carica papaya were 357.00, 340.50, 329.75, and 326.50, and 465.75, 450.50, 401.50, and 392.75 after the first and second rounds of spray, respectively. **Tables 3 and 4** show that the control had the fewest healthy leaves (281.25 and 228.50, respectively).

The percentage of infected leaves after treatment with Capsicum sp, Zingiber officinale, Moringa oleifera, and Carica papaya were 4.05, 4.61, 5.31, and 5.74, and 4.02, 5.38, 18.66, and 19.92, and 25.30, 32.10, 35.18, and 39.08 after the first, second, and third sprays, respectively **(Tables 3-5)**. The greatest percentage of leaf infection was detected from the untreated control 10.48, 65.31, and 99.97% following the first, second, and third round sprays, respectively **(Tables 3-5)**.

The mean flower number was recorded after treatment application of Capsicum sp., *Zingiber officinale*, *Moringa oleifera,* and Carica papaya, and the results were 20.50, 19.25, 18.50, and 17.50 after 3rd round of spraying **(Table 6)**. The lowest number of flowers, 12.75, was obtained from the control **(Table 5)**.

The percentage of infected flowers was recorded after treatment application of Capsicum sp., *Zingiber officinale*, *Moringa oleifera,* and Carica papaya, showing 15.37, 17.14, 18.96, and 21.35 after the 3rd round spray **(Table 5)**. The highest (80.30%) of flower infestation was obtained from control **(Table 5)**.

The percent mortality of T. absoluta after the first, third, fifth, and seventh days was 26.77, 41.37, 44.73, and 47.89%; 54.05, 58.22, 64.46, and 71.06%; and 73.81, 78.06, 80.81, and 87.86 after the first, second, and third round sprays of the treatments, respectively. The application of Zingier officinale at a rate of 100 g/L caused percent mortality of T. absoluta after the first, third, fifth, and seventh days, giving 23.30, 33.80, 35.23, and 39.85%; 45.84, 52.57, 57.80, and 64.32%; and 66.07, 74.07, 78.07, and 84.07% after the first, second, and third rounds of treatment, respectively. Moringa oleifera at 100 g/L induced death of T. absoluta after the first, third, fifth, and seventh days, with mortality rates of 20.70, 29.60, 30.24, and 35.36%; 42.92, 46.84, 53.85, and 59.63%; and 61.13, 69.08, 73.83, and 79.83% for the first, second, and third round sprays. Carica papaya at 150 g/L also resulted in a mortality percentage of T. absoluta after the first, third, fifth, and seventh days of about 19.02, 26.31, 29.07, and 34.28%; 41.24, 43.75, 51.82, and 57.19%; and 58.94, 62.19, 70.19, and 72.19% for the first, second, and third round sprays, respectively. All plant preparations reduced the T. absoluta larval population within three days.

Table 3. Mean percent efficacy of botanicals on *T. absoluta* after 1st spray under Glasshouse Conditions.

Name of treatments	Rate gm/L or ml/L	TL	HL	% IL	Days after insecticide treatment			
					% mortality			
					1	3	5	7
***Capsicum* sp.**	75	371.50a	357.00a	4.05e	26.77a	41.37a	44.73a	47.89a
Zingiber officinale	100	351.00b	340.50b	4.61d	23.30b	33.80b	35.23b	39.85b
Moringa oleifera	100	347.25c	329.75c	5.31c	20.70c	29.60c	30.24c	35.36c
Carica papaya	150	344.75c	326.50c	5.74b	19.02d	26.31d	29.07d	34.28d
Control		310.75d	281.25d	10.48a	0.00e	0.00e	0.00e	0.00e
CV (%)		0.55	1.41	3.98	3.25	1.81	1.59	1.83
LSD at 0.01%		2.93	7.12	0.37	0.89	0.73	0.68	0.88
SE (±)		1.90	4.62	0.24	0.58	0.47	0.44	0.57

Note: There was no discernible difference between means that had the same letter or letters in the column.
At p<0.01 (LSD), every treatment effect was extremely significant.
TL = number of total leaf, HL = healthy leaf, %IL = percentage of infected leaf, %mortality = percentage of mortality.

Table 4. Mean percent efficacy of botanicals on *T. absoluta* after 2nd spray under Glasshouse during 2021.

Name of treatments	Rate gm/L or ml/L	TL	HL	% IL	Days after insecticide treatment			
					% Mortality			
					1	3	5	7
***Capsicum* sp.**	75	484.50a	465.75a	4.02e	54.05a	58.22a	64.46a	71.06a
Zingiber officinale	100	480.25b	450.50b	5.38d	45.84b	52.57b	57.80b	64.32b
Moringa oleifera	100	474.75c	401.50c	18.66c	42.92c	46.84c	53.85c	59.63c
Carica papaya	150	467.25d	392.75d	19.92b	41.24d	43.75d	51.82d	57.19d
Control		377.75e	228.50e	65.31a	0.00e	0.00e	0.00e	0.00e
CV (%)		0.48	0.73	2.46	1.06	1.31	1.00	0.75
LSD at 0.01%		3.39	4.38	0.86	0.60	0.81	0.70	0.58
SE (±)		2.20	2.84	0.55	0.39	0.52	0.45	0.37

Note: There is no discernible difference between the means that have the same letter (s) in the column.
At p<0.01, every treatment effect was extremely significant.
TL = number of total leaf, HL = healthy leaf, %IL = percentage of infected leaf, % mortality = percentage of mortality.

Table 5. Mean percent efficacy of botanicals on *T. absoluta* after 3rd spray under Glasshouse Conditions.

Name of treatments	Rate gm/L or ml/L	% IL	Fl No.	IFl	Days after insecticide treatment			
					% mortality			
					1	3	5	7
***Capsicum* sp.**	75	25.30e	20.50a	15.37e	73.81a	78.06a	80.81a	87.86a
Zingiber officinale	100	32.10d	19.25b	17.14d	66.07b	74.07b	78.07b	84.07b
Moringa oleifera	100	35.18c	18.50b	18.96c	61.13c	69.08c	73.83c	79.83c

Carica papaya	150	39.08b	17.50c	21.35b	58.94d	62.19d	70.19d	72.19d
Control		99.97a	12.75d	80.30a	0.00e	0.00e	0.00e	0.00e
CV (%)		1.02	3.05	1.65	0.84	0.93	0.40	0.75
LSD at 0.01%		0.73	0.83	0.77	0.67	0.81	0.37	0.75
SE (±)		0.47	0.54	0.50	0.43	0.52	0.24	0.48

Note: Means with the same letter (s) in the column are not significantly different from each other.
All treatment effects were highly significant at p<0.01.%
Where: IL = percentage of infected leaf, Fl No. = flower number, %IFl = percentage of infected flower % mortality = percentage of mortality.

Effect of botanicals on yield and yield components of tomato

The findings showed that the mean plant height varied somewhat across most treatments, but not significantly ($p > 0.05$). The highest height (93.15 cm) of the plant was recorded from a plant treated with *Capsicum* sp., and the lowest (79.17 cm) height was obtained from the control in **Table 6** A maximum weight of a single fruit was recorded on positive treatment with Capsicum sp. (62.50 gm/plant), followed by *Zingiber officinale*, *Moringa, oleifera* and *Carica papaya (*60.00, 58.25 and 56.25 gm/plant). There was a significant difference among treatments, respectively. The lowest 38.25 gm/plant weight of a single fruit was recorded in the untreated control treatment in **Table 6**. However, there were notable variations amongst the treatments in terms of marketable fruit weight per plant. The highest weight (872.70 gm) of marketable fruit was obtained from *Capsicum* sp., followed by *Zingiber officinale*, *Moringa oleifera,* and *Carica papaya, which* were 871.50, 870.12, and 869.00 gm, respectively. The lowest weight (210.50 gm) of marketable fruit was found in the control **(Table 6)**.

The results revealed that there was a significant difference in the weight of fruit yield ($p > 0.05$) in all treatments. The maximum yield was obtained from *Capsicum* sp.-treated plants (1020.50 gm/plant), followed by *Zingiber officinale*-treated plants (1018.50 gm/plant), *Moringa oleifera* (1017.50 gm/plant), and *Carica papaya* (1012.50 gm/plant). Whereas the lowest weight of tomato yield was obtained from the control plants (250.50 gm/plant). The total percentages of yield losses ranged from 26.56 to 99.55% if the experiment was not treated either with botanicals, and Synthetic insecticides (Febriandika *et al*., 2023; Huyen *et al*., 2023; Keliddar *et al*., 2023).

Table 6. Mean percent efficacy of botanical on *T. absoluta* on different yield attributes of tomato under Glasshouse.

Treatments	Rategm/L or ml/L	Average single fruit weight in gm	Marketable fruit wt/plant in gm	PH (cm)	Total fruit yield/plant in gm	% yield loss
***Capsicum* sp.**	75	62.50a	872.70a	93.15a	1020.50a	9.18e
Zingiber officinale	100	60.00b	871.50b	91.67ab	1018.50b	11.33d
Moringa oleifera	100	58.25c	870.12c	91.60ab	1017.50c	19.08c
Carica papaya	150	56.25d	869.00d	89.75b	1012.50d	26.56b
Control		38.25e	210.50e	79.17c	250.50e	99.55a
CV (%)		0.79	0.08	2.09	0.07	1.54
LSD at 0.01%		0.67	0.97	2.87	0.93	0.79
SE (±)		0.43	0.63	1.86	0.60	0.51

Note: Means with the same letter (s) in the column are not significantly different from each other.
All treatment effects were highly significant at p<0.01.
PH = plant height, gm = gram, cm = centimeter, L = liter, ml = milliliter, wt = weight

Discussions

Results of the analysis revealed that botanical insecticides were found to be effective against leaf miner (*Tuta absoluta*) even though their efficacy level varied in mortality of larvae. Botanical pesticides are regarded as plant protection techniques that are inherently safe and innocuous to customers' and users' health. Additionally, plant pesticides are simpler to make and less costly. In the current investigation, locally available plants with certain insecticidal properties showed different levels of efficacy against *Tuta absoluta* larvae. Under laboratory conditions, there were significant differences between botanical extracts tested in causing mortality to *Tuta absoluta* larvae. Under glasshouse conditions in the 1st to 3rd round spray at every ten (10) day interval, the glasshouse treated with botanicals and insecticides revealed significant differences in mortality of *Tuta absoluta* (Adam, 2024; Garbarova *et al*., 2024; Nguyen *et al*., 2024).

In the present studies, *Capsicum* sp. at the rate of 75 g/L caused the highest percent mortality (87.86%) of *Tuta absoluta* on the 7th day after the 3rd round of spray under the glasshouse. These results are similar to earlier research by Aslam *et al*. (2002), which tested six types of plant powders against C. chinensis and found that clove and black pepper effectively protected tomatoes from the beetle. Nadra (2004) and Dehaghi *et al*. (2022) also found that Capsicum fruit significantly killed 85% of Trogoderma granarium adults at all tested concentrations within 7 days. This was confirmed by Antonious *et al*. (2007) and Ashkevari *et al*. (2023), who demonstrated the insecticidal qualities of chili peppers. Extracts from chili peppers have been utilized to control several pests in field experiments, and the outcomes matched those of this investigation. This study, which showed that formulations based on chili peppers have insecticidal action, was further corroborated by Antonious *et al*. (2007). Lepidopteran and Thysanopteran pests have been managed with chili pepper aqueous extracts in field application trials (Amoabeng *et al*., 2013; Fening *et al*., 2013, 2014; Baidoo & Mochiah, 2016; Okrikata *et al*., 2016; Oran *et al*., 2022; Perwitasari *et al*., 2023), but the outcomes were in line with this investigation.

Zingiber officinale at the dose of 100 g/L caused percent mortality (84.07%) of *Tuta absoluta* on the 7th day after the 3rd round of spray under the glasshouse. On the 7th day following the third session of spraying beneath the glasshouse, Moringa olifera at a rate of 100 g/L produced a promising percent mortality (79.83%) of Tuta absoluta. These findings were confirmed by Baidoo and Adam (2012) and Tural *et al*. (2023), who found that extracts from the leaves and roots of Moringa oleifera are efficient plant growth regulators and biopesticides against a variety of chewing and sucking insect pests. Seven days following the third round of spraying beneath the glasshouse, Tuta absoluta mortality was 72.19% due to carica papaya at a rate of 150 g/L. Figueroa-Brito (2002) revealed 100% larval mortality of S. frugiperda at doses of 10, 15, and 20% using powder of the cultivar Mammee in earlier research using powdered C. papaya seeds.

Yield loss ranged from 3.61 to 26.56% with treated plants as compared to the untreated control (99.55%). This finding was in conformity with Desneux *et al*.'s (2010) study, which reported yield losses due to *T. absoluta* causing 50–100% as a result of the direct and indirect damage.

CONCLUSION

The present findings indicated that botanical extracts were found to be effective against tomato leafminer in 10-day intervals of 3 round sprays. Among the botanicals, *Capsicum* sp. and *Zingiber officinale* had high efficacy in terms of causing high mortality in *T. absoluta* larvae. Botanicals are accessible, affordable, and environmentally beneficial solutions for managing insect pests. Furthermore, the improvement of Ethiopian farmers' livelihoods depends on the effective development of IPM tactics in tomatoes, which is made impossible by the dearth of current knowledge on botanical extracts. For sustainable and environmentally beneficial T. absolut management techniques, plant substitutes must be created. The effectiveness of plant remedies against the main insect pests should be investigated further in this work. Thus, mechanisms of action, product availability, and repeat studies under various agro-ecological situations should be the main areas of future study.

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