EFFICACY EVALUATION OF COMMERCIAL INSECTICIDES FOR THE MANAGEMENT OF TOMATO LEAF MINER *(Tuta Absoluta)* IN TOMATO IN BHARATPUR, CHITWAN

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ABSTRACT

Tomato leaf miner (Tuta absoluta) is one of the most destructive pests affecting tomato crop. In Nepal, it is currently one of the major pests spreading all over the country after its first appearance in May 2016 in Kathmandu valley. A field experiment was conducted to evaluate the efficacy of commercial insecticides against tomato leaf miner in Bharatpur, Chitwan, Nepal. This experiment was laid out in a randomized complete block design with six treatments and four replications. The different treatments included: i) Azadirachtin 1500 ppm (dose: 5 ml/liter), ii) Emamectin benzoate 1.5% + Indoxacarb 7.5% SC (dose: 0.625 ml/liter), iii) Spinetoram 11.7% w/w SC (dose: 0.5 ml/liter), iv) Bifenthrin 10% + Dinotefuran 20% SC (dose: 4ml/liter), v) Emamectin benzoate 5.7% WDG (dose: 0.3125 gm/liter) and vi) control (water spray). Treatments were applied 3 times at 10 days intervals and data were recorded at 3 Days After Spray (DAS), 6 DAS, and 9 DAS. The lowest percentage of leaf and fruit damage was recorded on spinetoram followed by emamectin benzoate + indoxacarb and emamectin benzoate. Similarly, the highest percentage of population reduction over control in leaves was observed in spinetoram (64.50%) followed by emamectin benzoate + indoxacarb (63.59%) and emamectin benzoate (59.43%) and the highest percentage of population reduction over control in fruits was observed in spinetoram (86.83%) followed by emamectin benzoate (83.53%) and emamectin benzoate + indoxacarb (80.24%). Maximum yield (44.71mtha^{-1}) was obtained in spinetoram treated plots whereas minimum was in control (38.03mtha^{-1}). The highest Benefit/Cost ratio was obtained in spinetoram (1.72) followed by emamectin benzoate (1.63) and emamectin benzoate + indoxacarb (1.60). Thus, spinetoram was found to be a superior insecticide for the management of Tuta absoluta followed by emamectin benzoate + indoxacarb and emamectin benzoate under field conditions in Bharatpur, Chitwan.

Keywords: *Population reduction over control, Larval mortality, Leaf damage, Fruit damage, yield*

INTRODUCTION

Tomato (*Solanum lycopersicum*, 2n=2x=24) is a major vegetable crop of Nepal, which is commonly attacked by a wide range of insects, among which the tomato leaf miner (*Tuta absoluta*) stands out as a significant pest and is estimated to cause a loss of 85-90% of the total production (de Medeiros et al., 2005 ; Soti et al., 2020). *Tuta absoluta* is a small moth belonging to the Lepidoptera order, known for its high reproductive capacity and undergoes 10-12 generations per year, with a complete life cycle lasting 30-35 days (Harizanova et al., 2009). *T. absoluta* originated in South America was reported since the 1980's and then rapidly invaded many Mediterranean and European countries (Braham & Hajji, 2012). *Tuta absoluta* was documented in Maharashtra, India, in October 2014, and Nepal in May 2016, as its presence was observed across altitudes ranging from 725 meters above sea level (masl) to 1664 masl, showcasing the pest's diversity and subsequently, it gradually spread throughout the country (Bajracharya et al., 2016).

The life cycle of *T. absoluta* comprises four main developmental stage: egg, larvae, pupae and adult. Eggs which are initially creamy white but gradually changes into a light yellow were deposited on the upper and lower surface of the leaves and the larvae passes through 4 instars, with initially being creamy white and later greenish and then pinkish color (Bajracharya & Bhat, 2018). Leaves and stems are preferred by this, but they can also be found in fruits or under or in the crown of the fruits. Near the entrance hole, small heaps of excrement are often found. The most distinctive symptoms of the presence of the species are the blotch-shaped mines in the leaves in which the caterpillars can be found with the prominent irregular and discolored pattern of leaves. Larvae are responsible for boring in the apical buds and stem, leaving for leaf folding and further tunneling in the near fruits and leaving frass occupied galleries (Bajracharya et al., 2016). *T. absoluta* larvae cause serious infestation by boring inside the fruit that subsequently rendered the fruit quality and with further secondary infection, leaving skin hanging with consumed internal contents and accelerated senescence of fruits (Harizonova et al., 2009)

Various management options are available for controlling *T. absoluta* which includes chemical control, biological control, cultural and other IPM methods (Ghoneim, 2014). The employment of chemical pesticides is widely followed as the primary means to control *T. absoluta* infestations, recognized as the most efficient approach (Illakwahhi & Srivastava, 2017). Farmers have increasingly realized that traditional insecticides like organophosphates and carbamates weren't effective against this insect (Braham & Hajji, 2012). The aim of this study isn't to promote one insecticide over another but to broaden the range of effective insecticides with varying modes of action. These investigations showcase the effectiveness of several commercial insecticides and the most economical insecticides for the farmers such as spinetoram, emamectin benzoate, indoxacarb, azadirachtin, dinotefuran and bifenthrin.

MATERIALS AND METHODS

The research was conducted at the Research Farm of Muktinath Krishi Company Limited which lies in Bharatpur metropolitan city, Chitwan in Bagmati province of Nepal. Geographically, the experimental field lies at latitude 27.9652^0 N and longitude 84.3201^0 E which is located at an altitude of 251 masl. The average pH of soil of the experimental field was 5.7. The experiment was conducted in tomato crop (Srijana F1 hybrid variety) between February 2024 to May 2024. The field experiment was laid out in a Randomized Complete Block Design (RCBD) with six treatments and replicated four times.

The total population of field was 432 plants, containing 18 plants per plot. The spacing between plant to plant was 0.45m and row to row was 0.75m. Spacing between treatments was 0.5m and replications was 1m (Table 1, Figure 1). From each plot, 6 sample plants were selected randomly and data from those sample plants were observed and recorded carefully. The farm yard manure was applied at the rate of 15 mt/ha and fertilization of nitrogen, phosphorous and potassium was done at the rate of 150:120:100 NPK kg/ha (AITC, 2023). The plot size was maintained at $6.075m^2$ (2.7m x 2.25m). The monitoring tool containing "tuta lure" along with trap was kept near the field and application of treatment was done after the dead adult male moth captured in trap reaches to 153 within 48 hours in which the plants were 44 days of transplanting.

As the pest population surged in monitoring traps in another field, application of treatment application was initiated 45 days after transplanting. The treatments were applied three times at 10 days interval and the data of pre-treatment was recorded 24 hours before application of treatment and post treatment was recorded 3 days after spray, 6 days and 9 days after each spray. Fruiting and infestation were observed after second spray. Measuring cylinder (100 ml capacity) was used to measure the volume of liquid insecticide while a weighing balance (Skyking, MH Series, 200 grams capacity) was used to measure the insecticide in the form of granules or powder. Separate and clean knapsack sprayer of 16-liter capacity was used for the spraying of the treatments and spraying was done in evening time.

Table 1: Details of the treatments used in the field experiment

T	Treatments	Dosages	Trade name	Type
T1	Azadirachtin 1500 ppm	5 ml/lt. of water	M-Neem ultra-1500	Neem plant origin-systemic
T2	Emamectin benzoate 1.5% + Indoxacarb 7.5% SC	0.625 ml/lt. of water	M-Titan	Synthetic-contact and stomach toxicity
T3	Spinetoram 11.7% w/w SC	0.5 ml/lt. of water	Delegate	Bacterial origin- nervous system toxicity
T4	Bifenthrin 10% + Dinotefuran 20% SC	4 ml/lt. of water	M-Rapido	Synthetic-Neurotoxin
T5	Emamectin benzoate 5.7% WDG	0.3125 gm/lt. of water	M-Benzo max	Synthetic-contact and stomach toxicity
T6	Control	Sprayed with water		

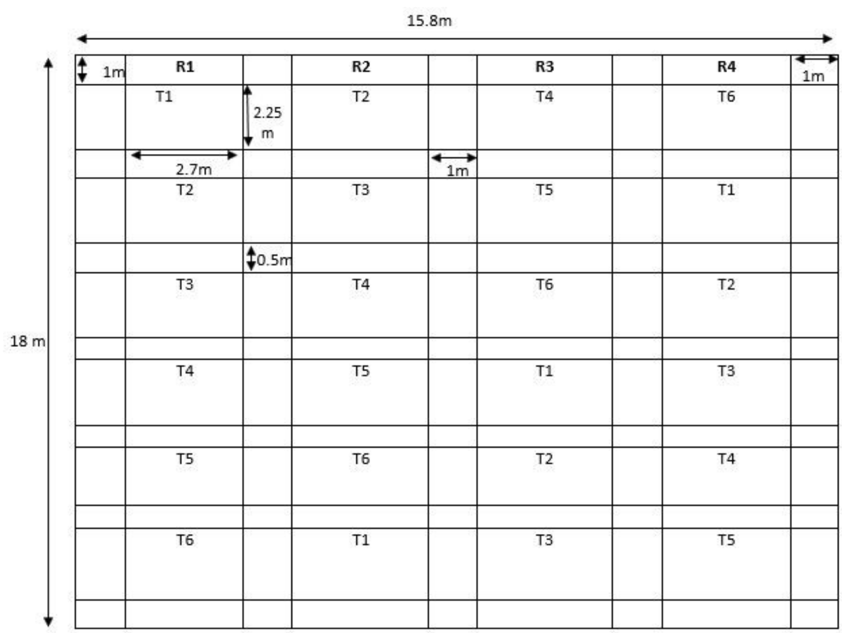

Figure 1. Layout of research field at Bharatpur, Chitwan

The observation parameters are as follows:

Percentage of Leaf Infested (PLI)

The data of the number of infested leaves in the sample plant and the total number leaves in the sample plant was taken and the calculation of the percentage of leaf infestation was recorded by:

PLI (%) = (NLSP/TLSP) ×100

Where,
NLSP: Number of infested leaves in sample plants
TLSP: Total number of leaves in sample plant

Percentage of Fruit Infested (PFI)

The data of the number of infested fruits in the sample plant and the total number of fruits in the sample plant was taken and calculation was done by:

PFI (%) = (NFSP/TFSP) ×100

Where,
NFSP: Number of infested fruits in sample plants
TFSP: Total number of fruits in sample plants

Calculation of percentage reduction of larvae/ leaf over control

At first, 5 leaves from infested leaves from sample plants of each plot were picked out randomly, then the population of live larvae was observed and recorded from those leaves, and the population of average larvae per leaf was calculated.

The average proportion of decreased larvae population resulting from treatments was computed as the Percentage Reduction Compared to the Control (PROC) (Abbott, 1925).

% population reduction of leaves = [1- ((Ta/Tb) × (Cb/Ca))] × 100

Where,
Ta: Post-treatment population in the treatment of leaves
Tb: Pre-treatment population in the treatment of leaves

Cb: Pre-treatment population in control of leaves Ca: Post-treatment population in control of leaves

Calculation of percentage reduction of larvae/ fruit over control

At first, 5 infested fruits from sample plants of each plot were picked out randomly, and live larval population was counted and the average population per fruit was calculated. For this, destructive sampling was done as larvae of *Tuta absoluta* mines inside the fruit.

The average proportion of decreased larvae population resulting from treatments was computed as the Percentage Reduction Compared to the Control (PROC) (Abbott, 1925).

$$\% \text{ population reduction of fruits} = [1- ((Ta/Tb) \times (Cb/Ca))] \times 100$$

Where, Ta: Post-treatment population in the treatment of fruits
Tb: Pre-treatment population in the treatment of fruits
Cb: Pre-treatment population in control of fruits
Ca: Post-treatment population in control of fruits

Yield

Six sample plants were harvested and are harvested 3 times at 7 days intervals after 75 days after transplanting as it is indeterminate type and is weighed with the help of weighing balance (Honda 100 Kg capacity) from each plot. And average per plant was calculated from the following:

Yield per plant = Cumulative weight of yield of total sample plants / total number of sample plants

The total yield of tomatoes per plant was recorded and after harvesting it was converted into metric tons per hectare.

Benefit cost analysis of different treatments

The cost of production, income and profit were calculated as the farm price of tomato was NRS. 13 per kg and benefit cost ratio of each treatment were calculated.

The initially collected data were entered in MS-Excel and data analysis was done by using the computer software R studio (version 4.4.1). The mean comparison was made with Duncan's Multiple Range Test at 5% level of significance.

RESULTS

Leaf infestation

Leaf infestation percentage was recorded in different days after the application of treatments. The leaf infestation percentage differed significantly with different treatments of commercial insecticides. Spinetoram (25.38%) was the most effective pesticide for reducing the leaf damage due to *Tuta absoluta* which was followed by emamectin benzoate + indoxacarb (31.32%) and emamectin benzoate (42.95%). The highest leaf infestation was recorded on control (64.74%) which was followed by azadirachtin (53.51%) and bifenthrin + dinotefuran (47.12%) (Table 2).

Table 2: Percentage of leaf infested on different days after spray, Bharatpur, Chitwan, 2024

Treatments	Infested leaf (%)								
	First spray			Second spray			Third spray		
	3 DAS	6 DAS	9 DAS	3 DAS	6 DAS	9 DAS	3 DAS	6 DAS	9 DAS
Azadirachtin	25.64^{ab}	34.96^{b}	44.71^{b}	43.55^{b}	46.30^{b}	47.92^{b}	51.49^{b}	53.29^{b}	53.51^{b}
Emamectin benzoate + Indoxacarb	21.36^{c}	26.75^{d}	31.81^{d}	30.77^{d}	32.06^{d}	32.26^{d}	32.39^{e}	32.20^{e}	31.32^{e}
Spinetoram	23.01^{bc}	32.46^{bc}	30^{d}	27.45^{e}	26.79^{e}	27.18^{e}	26.25^{f}	25.93^{f}	25.38^{f}
Bifenthrin + Dinotefuran	24.95^{b}	35.04^{b}	42.08^{bc}	42.22^{b}	43.87^{b}	44.94^{bc}	46.28^{c}	46.99^{e}	47.12^{c}
Emamectin benzoate	23.74^{bc}	32.46^{bc}	38.42^{c}	38.85^{c}	40.74^{c}	41.69^{c}	42.54^{d}	42.99^{d}	42.95^{d}
Control	27.82^{a}	44.97^{a}	54.96^{a}	54.51^{a}	55.73^{a}	60.87^{a}	63.26^{a}	65.43^{a}	64.74^{a}
CV%	6.8	9.1	6.06	4.38	4.15	5.6	5.5	5.07	5.2
SEM (±)	0.84	1.53	1.22	0.87	0.85	1.19	1.2	0.68	1.15
$LSD_{0.05}$	2.5	4.62	3.68	2.61	2.56	3.58	3.62	2.06	3.46
F-test	**	***	***	***	***	***	***	***	***
Grand mean	24.42	33.71	40.33	39.56	40.92	42.47	43.7	44.48	44.17

Note: ** significant at 1% level of significance, *** significant at 0.1% level of significance, Sem – Standard Error of mean, CV – Coefficient of Variation, LSD – Least Significance Difference.

Fruit infestation percentage

Spinetoram (9.60%) was found to be most effective insecticides which was followed by emamectin benzoate + indoxacarb (12.47%). Control (20.02%) shows the highest fruit infestation due to *Tuta absoluta* which was statistically at par with azadirachtin (18.38%) (Table 3).

Table 3: Percentage of fruit infested on different days after second and third spray, Bh aratpur, Chitwan, 2024

Treatments	Infested fruit (%) Second spray			Infested fruit (%) Second spray		
	3 DAS	6 DAS	3 DAS	3 DAS	6 DAS	3 DAS
Azadirachtin	15.82^{a}	17.09^{a}	18.38^{a}	15.82^{a}	17.09^{a}	18.38^{a}
Emamectin benzoate + Indoxacarb	13.29^{b}	12.43^{c}	12.47^{c}	13.29^{b}	12.43^{c}	12.47^{c}
Spinetoram	11.41^{c}	10.17^{d}	9.60^{d}	11.41^{c}	10.17^{d}	9.60^{d}
Bifenthrin + Dinotefuran	14.70^{ab}	14.72^{b}	15.66^{b}	14.70^{ab}	14.72^{b}	15.66^{b}
Emamectin benzoate	14.78^{ab}	14.41^{b}	15.09^{b}	14.78^{ab}	14.41^{b}	15.09^{b}
Control	15.73^{a}	17.75^{a}	20.02^{a}	15.73^{a}	17.75^{a}	20.02^{a}
CV%	8.22	6.28	7.6	8.22	6.28	7.6
SEM(±)	0.59	0.45	0.58	0.59	0.45	0.58
$LSD_{0.05}$	1.77	1.37	1.74	1.77	1.37	1.74
F-test	***	***	***	***	***	***
Grand mean	14.29	14.43	15.21	14.29	14.43	15.21

Note: *** significant at 0.1% level of significance, SEM – Standard Error of mean, CV – Coefficient of Variation, LSD – Least Significance Difference.

Percentage of population reduction over control of larvae in infested leaf

Spinetoram was found most effective insecticide which restricted maximum *T. absoluta* larval population build up where up to 81.61% pest control was observed compared to control plot. Emamectin benzoate + indoxacarb was also found effective for reducing the larvae of *T. absoluta* up to 77.63% compared to control (Table 4, 5, and 6).

All the insecticides were able to reduce the population of larvae per leaf compared with the control except at 6 DAS of the 3rd spray in bifenthrin + dinotefuran and 9 DAS of the 3rd spray in the azadirachtin.

Table 4: PROC of larvae of *Tuta absoluta* per leaf in infested leaves after first spray, Bharatpur, Chitwan, 2024

Treatments	Pre-spray	PROC of larvae per leaf found in infested leaf — First spray					
		3 DAS		6 DAS		9 DAS	
		Avg. pop^{n}.	PROC %	Avg. pop^{n}.	PROC %	Avg. pop^{n}.	PROC %
Azadirachtin	0.55	0.45	33.59	0.39	61.03	0.44	58.62
Emamectin benzoate+ Indoxacarb	0.56	0.41	40.03	0.31	69.30	0.24	77.63
Spinetoram	0.57	0.39	43.72	0.25	75.57	0.2	81.61
Bifenthrin + Dinotefuran	0.53	0.43	33.85	0.36	62.50	0.29	71.57
Emamectin benzoate	0.51	0.42	32.19	0.33	63.92	0.27	72.22
Control	0.48	0.59		0.87		0.93	

Table 5: PROC of larvae of *Tuta absoluta* per leaf in infested leaves after second spray, Bharatpur, Chitwan, 2024

Treatments	PROC of larvae per leaf found in infested leaf						
	Second spray						
	Pre-spray	3 DAS		6 DAS		9 DAS	
		Avg. pop^n.	PROC %	Avg. pop^n.	PROC %	Avg. pop^n.	PROC %
Azadirachtin	0.44	0.42	12.29	0.41	19.45	0.51	4.66
Emamectin benzoate + Indoxacarb	0.24	0.19	27.25	0.14	49.58	0.13	55.44
Spinetoram	0.2	0.13	40.27	0.09	61.10	0.08	67.10
Bifenthrin + Dinotefuran	0.29	0.24	23.95	0.19	43.37	0.16	54.62
Emamectin benzoate	0.27	0.21	28.53	0.17	45.57	0.14	57.35
Control	0.93	1.01		1.07		1.13	

Table 6: PROC of larvae of *Tuta absoluta* per leaf in infested leaves after third spray, Bharatpur, Chitwan, 2024

Treatments	PROC of larvae per leaf found in infested leaf						
	Third spray						
	Pre-spray	3 DAS		6 DAS		9 DAS	
		Avg. pop^n.	PROC %	Avg. pop^n.	PROC %	Avg. pop^n.	PRO C%
Azadirachtin	0.51	0.48	9.53	0.51	3.88	0.55	-2.08
Emamectin benzoate + Indoxacarb	0.13	0.1	26.06	0.07	48.24	0.05	63.59
Spinetoram	0.08	0.05	39.92	0.03	63.95	0.03	64.50
Bifenthrin + Dinotefuran	0.16	0.14	15.89	0.34	-104.26	0.09	46.76
Emamectin benzoate	0.14	0.11	24.47	0.09	38.21	0.06	59.43
Control	1.13	1.17		1.17		1.19	

Percentage of population reduction over control of larvae in infested fruit

The highest population reduction percentage over the control of larvae of *Tuta absoluta* in infested fruit was observed in spinetoram where population was reduced up to 86.83%. The lowest reduction of population over control was found on bifenthrin + dinotefuran insecticide treated plots where population was reduced up to only 39% (Table 7 and 8). Also, most of the insecticides were able to reduce the population of larvae per fruit after each spray compared to that of control.

Table 7: PROC of larvae of *Tuta absoluta* per fruit in infested fruits after second spray, Bharatpur, Chitwan, 2024

Treatments	PROC of larvae per leaf found in infested leaf						
	Second spray						
	Pre-spray	3 DAS		6 DAS		9 DAS	
		Avg. pop^n.	PROC %	Avg. pop^n.	PROC %	Avg. pop^n.	PROC %
Azadirachtin	0.21	0.12	58.69	0.14	59.11	0.11	78.36
Emamectin benzoate + Indoxacarb	0.24	0.18	46.98	0.14	65.01	0.1	83.17
Spinetoram	0.26	0.17	53.30	0.35	18.41	0.09	85.87
Bifenthrin + Dinotefuran	0.22	0.19	39.00	0.15	59.14	0.13	76.15
Emamectin benzoate	0.22	0.18	42.22	0.15	59.14	0.12	77.99
Control	0.20	0.28		0.33		0.49	

Table 8: PROC of larvae of *Tuta absoluta* per fruit in infested fruits after third spray, Bharatpur, Chitwan, 2024

Treatments	PROC of larvae per leaf found in infested leaf						
	Second spray						
	Pre-spray	3 DAS		6 DAS		9 DAS	
		Avg. pop^n.	PROC %	Avg. pop^n.	PROC %	Avg. pop^n.	PROC %
Azadirachtin	0.11	0.09	41.90	0.08	67.31	0.06	78.45
Emamectin benzoate + Indoxacarb	0.1	0.08	43.19	0.06	73.03	0.05	80.24
Spinetoram	0.09	0.07	44.77	0.05	75.03	0.03	86.83
Bifenthrin + Dinotefuran	0.13	0.1	45.37	0.09	68.88	0.07	78.72
Emamectin benzoate	0.12	0.09	46.74	0.07	73.78	0.05	83.53
Control	0.49	0.69		1.09		1.24	

Yield

There was a significant variation in yield between different treatments. Here, the highest yield was obtained on spinetoram (44.71 mtha^{-1}) which was followed by emamectin benzoate + indoxacarb (42.59 mtha^{-1}). The lowest yield was recorded on control (38.03 mtha^{-1}) which was statistically at par with azadirachtin (38.98 mt/ha) followed by bifenthrin + dinotefuran (41.34 mtha^{-1}) which was statistically at par with emamectin benzoate (42.06 mtha^{-1}) (Table 9).

Table 9: Effects of different treatments on yield per hectare (mt/ha) of tomato, Bharatpur, Chitwan, 2024

Treatments	Yield ($mtha^{-1}$)
Azadirachtin	38.98^{d}
Emamectin benzoate + Indoxacarb	42.59^{b}
Spinetoram	44.71^{a}
Bifenthrin + Dinotefuran	41.34^{c}
Emamectin benzoate	42.06^{bc}
Control	38.03^{d}
CV%	9.11
SEM(±)	5.14
$LSD_{0.05}$	3.45
F-test	***
Grand mean	41.29

Note: *** significant at 0.1% level of significance, SEM – Standard Error of mean, CV – Coefficient of Variation, LSD – Least Significance Difference.

Benefit-cost analysis of different treatments

It is concluded that the highest income was generated in spinetoram treated plots followed by Emamectin benzoate + indoxacarb and Emamectin benzoate. The highest cost was recorded on azadirachtin-treated plots. The net profit and Benefit-cost ratio were found highest on spinetoram (1.72) treated plots which were followed by Emamectin benzoate (1.63) treated plots and Emamectin benzoate + indoxacarb (1.60) treated plots. The lowest profit and benefit-cost ratio was found in azadirachtin-treated plots

(Table 10). Table 10: Benefit cost analysis of different treatments, Bharatpur, Chitwan, 2024

Treatments	Yield (kg/ha)	Income (NRs/ha)	Cost (NRs/ha)	Net profit (NRs/ha)	Benefit cos
Azadirachtin	38980	5,06,740	2,29,957.9	2,76,782.2	1.20
Emamectin benzoate + Indoxacarb	42590	5,53,670	2,12,552.8	3,41,117.3	1.60
Spinetoram	44710	5,81,230	2,13,924.1	3,67,306	1.72
Bifenthrin + Dinotefuran	41340	5,37,420	2,34,346	3,03,074	1.29
Emamectin benzoate	42060	5,46,780	2,07,805.9	3,38,974.1	1.63
Control	38030	4,94,390	2,04,641.4	2,89,748.7	1.42

Note: Farm price of tomato was NRs. 13 per kg in May, 2024

DISCUSSION

Spinoteram was observed the most effective insecticide and this result is in line with research conducted by Sridhar et al. (2019), where spinetoram was most toxic on *Tuta absoluta*, followed by spinosad then by emamectin benzoate. Spinoteram disrupt the nicotinic/gamma amino butyric acid (GABA)- gated chloride ion of the pest. These effects were concentration-dependent and the number of applications. Of the tested bio-insecticides, emamectin benzoate gave the lowest efficacy as percentage infestation by *Tuta absoluta* of 28.3% (Hanafy & El-Sayed, 2013) whereas the lowest infestation of fruits was found in chlorantraniliprole (0.133). The highest fruit infestation was found in control (8.865) which is similar to the finding of Bastola et al. (2020). *Bacillus thuringiensis* and azadirachtin with an average mortality of 67.29% and 66.40% showed the lowest effect, respectively. In another experiment conducted by Hosseinzadeh and Aramideh (2019) *Bacillus thuringiensis* and azadirachtin showed insecticidal efficacy compared with thiocyclam on tomato leaf miner was also is in line with this finding. Nevertheless, indoxacarb tends to be a powerful suppressor of *T. absoluta* larvae (Braham & Hajji, 2012).

Our finding is in line with Shimokawatoko et al. (2012), where spinetoram was effective and it acts as an allosteric modulator of nicotinic acetylcholine receptors, enhancing the effects of acetylcholine, which leads to overstimulation of the nervous system. Emamectin benzoate functions primarily as a neurotoxin in insects (Fanigliulo & Sacchetti, 2008). Indoxacarb is an effective insecticide widely used for controlling various insect pests, particularly lepidopteran larvae. Indoxacarb binds to specific sites on the sodium channels in insect neurons, inhibiting their function. This blockage prevents the normal flow of sodium ions, influencing to paralysis and eventual death of the insect. It selectively affects the slow- inactivated states of sodium channels, which is a unique feature that differentiates it from other sodium channel inhibitors (Von Stein et al., 2013). According to Rwomushana et al. (2019), the feeding habits of *Tuta absoluta* make its presence difficult to detect in the early infestation period, results in severe damage to plants. *T. absoluta* infestation results in significant yield losses of tomato and other crops, including a reduction in crop quality. Due to loss in quality, the weight of infested fruit will decrease due to senescence and yield will decrease.

CONCLUSION

The *Tuta absoluta* is one of the major pests of tomato farming causing severe reduction in the yield. Spinetoram was found to be most effective for reducing larval population and its damage in leaves and fruits followed by emamectin benzoate + indoxacarb and emamectin benzoate in field condition. It was also concluded that the most economical pest control method and highest yield was obtained in spinetoram treated plot. Therefore, Spinetoram and combination of emamectin benzoate and indoxacarb are recommended for the management of *Tuta absoluta* in the field condition.

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