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Bioassay of Plant-based and Synthetic Insecticides for the Management of Tomato Leaf Miner, *Tuta absoluta* (Meyrick) in Open-field Conditions in Salyan, Nepal

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Abstract

The tomato leaf miner, Tuta absoluta (Meyrick) (Lepidoptera: Gelechiidae), has invadedmost parts of Nepal and threatens tomato production. Their management primarily relieson insecticides in Nepal.Market-available and locally-madeplant-based pesticides are not equally effective in managingT. absoluta. Therefore, this study aimed to evaluate the effectiveness of such potential insecticides in managingT. absoluta in open-field conditions. This study was carried out in the Salyan district of Nepal in 2021 and treatments were designed in a randomized complete block design (RCBD)with seven treatments and three replications.All treatments were sprayed at12-dayintervalsfor two times. The treatments used were Emamectin benzoate 5% SC, Imidacloprid 17.8 SL, Jholmol (botanical mixture extract and urine mixture), Chlorantraniliprole 18.5 SC, Spinosad 45 SC, Azadirachtin 300ppm and Control. The results showed that the lowest percentage of leaves and fruit damage was recorded inChlorantraniliprole 18.5 SC and Spinosad 45 SC sprayed plots. Insecticide efficiency was ranked as Chlorantraniliprole > Spinosad>Emamectin Benzoate > Azadirachtin >Imidaclropid>Jholmol> Control.Marketable yield was obtained highest in Chlorantraniliprole (85.26 t/ha) treated plots followed by Spinosad (79.26 t/ha); both were not significantly different. This study provides an opportunity to select the most suitable and effective pesticides for the management of tomato leaf miners and can be used in integrated pest management strategies as a selective insecticides.

Keywords: Integrated pest management, solanaceous, chlorantraniliprole, spinosad

Introduction

The tomato leaf miner (*Tuta absoluta*), a member of the Gelechiidae family, is a key pest of solanaceous plants such as tomatoes and potatoes (Wang, Ferguson, & Shipp, 1998). This species is identified by observing the shape of the valve and vinculum in male genitalia (Povolny, 1975) or using barcoding on cytochrome oxidase I (COI) genes (Zhang et al., 2013). It can oviposit and develop its life stages on several plants belonging to the Amaranthaceae, Convolvulaceae, Fabaceae, and Malvaceae (Bawin et al., 2016). *Tuta absoluta* development is optimal at 30°C, but no development or reproduction occurs at low temperatures (Cuthbertson et al., 2013).

This pest was introduced in Nepal with its first record on May 2016 from the Kathmandu Valley (Bajracharya et al., 2016), and now is becoming a serious pest of tomato crops in both plastic houses and open-field conditions. This invasive pest affects the yield and quality of tomatoes up to 50-100 % in newly invaded areas where no any management methods are being implemented (Desneux et al., 2011). The punctures on the tomato fruit made by this insect can cause secondary infection on the tomato fruit (Kaoud, 2014).

The inadequate knowledge of farmers about pest management practices is the major setback to managing this pest in plastic houses and open-field conditions in the Salyan district of Nepal. Farmers are mostly dependent on synthetic insecticides to control tomato pests including *T. absoluta*. Pesticide dealers have influenced the local farmers to select the pesticides as per their interest. Such recommended pesticides are not equally effective and efficient in managing this pest in local areas. Some pesticides are not eco-friendly and can't be afforded by small and poor farmers. Hence, this study aimed to solve these problems by testing such insecticides in open field conditions. The selection of the most suitable and efficient pesticides can reduce input costs and improve the income of farmers. Broadly, synthetic chemicals are more effective than other plant-based pesticides and biopesticides. However, such synthetic chemicals have direct negative impacts on the environment, biodiversity, and human health (Ali et al., 2021). Integrated pest management (IPM) strategies are widely suggested to keep the pest population below the threshold level (Way & Van Emden, 2000). IPM practices reduce the chemical pesticides in agricultural fields and promote agroecological and organic farming (E. Birch et al., 2011).

Research Methodology

This study was conducted in Kapurkot-03 (28°13´26" N, 82°21'35" E) Salyan, Nepal. The experiment plot was thoroughly plowed, and the recommended dose of fertilizer and manure was used as per the recommendation by AITC (2023). Weeding and irrigation were done as per the requirements. The field experiment was designed in a thrice-replicated RCBD design with a total of seven treatments. Individual plot size was 4.5 m^2 (3 × 1.5 m) with a total of 21 plots and the total experiment area was 159.5 m^2 (Length: 14.5

m and Width: 11 m). Plants were grown in 60 cm for row-to-row spacing and 30 cm for plant-to-plant. 53-day-old tomato seedlings cv Heem-Shona, an indeterminate type, were transplanted in each plot.

Four popular chemical insecticides, two plant-based pesticides, and a control (water spray) were used (Table 1). The first spray of treatments was made on 86-day-old tomato seedlings on April 9, 2021.

Figure 1

Map showing experiment site (Kapurkot Rural Municipality-3, Salyan)

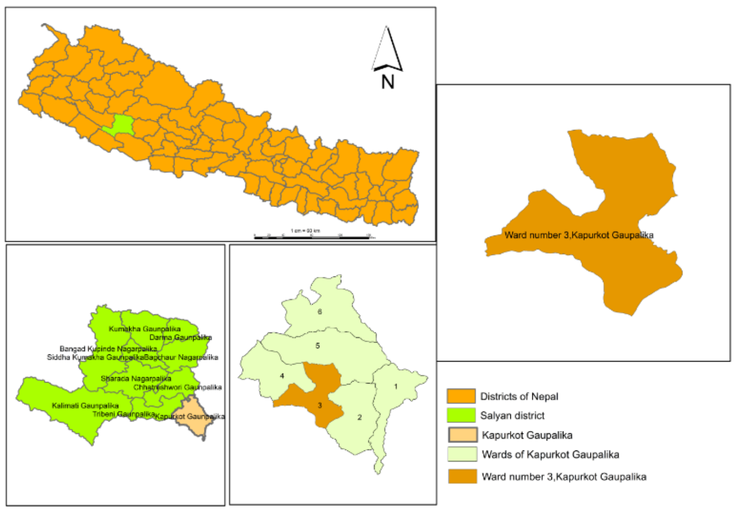


Table 1

Bioassay materials to test their effectiveness for T. absoluta

Treatments	Trade Name	Active Ingredient %	Formulation type	Dose	Chemical Group
Emamectin benzoate	Kingstar	5	SC	2 g/Liter	Avermectin
Imidaclo-prid	Aceme-pride	17.8	SL	0.3 mL/ Liter	Nicotinoid
Jholmol	-	-	-	1:3	Botanical
Chlorantra-niliprole	All Chlo-ra	18.5	SC	0.3 mL/ Liter	Avermectin
Spinosad	Tracer	45	SC	0.12 mL/ Liter	Spinosyn
Azadirach-tin	Bio-neem	300	EC	5 mL/ Liter	Botanical
Water	-	-	-	-	-

Note: SC-Suspension Concentrate, SL-Soluble Liquid, EC-Emulsifiable Concentrate, ppm- parts per million. Jholmol was prepared from locally available 3 kg botanical plants (Asuro, Titepati, and Lantana); 25 liters of cow urine; 50 g of chilly; 25 g of cardamom; 10 g of clover; 25 g of garlic; 25 g of onion; 250 g of turmeric powder; and 25 liters of water. It was fermented for 4 weeks and mixed with water in a ratio of 1:3, so a dose of 333 mL/liter was sprayed.

Data Collection and Analysis

Five sample plants in each plot were randomly selected and tagged for data observations. The pre-spray observation was taken one day before the application of treatments, and the following data was observed on 6 DAS (Days after spray) and 12 DAS. The second spray was done on the 98-day-old tomato plants on April 21, 2021. Similarly, data was collected one day before spraying, 6 DAS and 12 DAS. The percentage of leaves infested (PLI) was calculated using the formula, PLI (%) = , Where NLSP is the number of infested leaves in sample plants and TLSP is the total number of leaves in the sample plant. Similarly, the percentage of fruits infested (PFI) was calculated using the formula, PFI (%) = ×100, where NFSP is the number of infested fruits in sample plants and TFSP is the total number of fruits in sample plants. Marketable yield and net yield were measured using a digital weighing machine. The data was analyzed using RStudio (R version 4.1.1, Agricolae, gvlma package), and means comparisons were done by using Ducan's multiple-range test (DMRT) at a 5% level of significance (Gomez & Gomez, 1984).

Results and Discussion

Percentage of Tomato Leaves and Fruits Infested by *T. absoluta*

The percentage of infested leaves by *T. absoluta* was influenced by the application of insecticides in all treatments and all days (Table 2). At 6 days after the first spray, the lowest number of infested leaves was recorded in Spinosad (11.76 %), which was statistically at par with the Chlorantraniliprole (13.17%) sprayed plot. Similarly, the highest infestation of leaves was recorded in the control plot (31.56%), which was statistically similar to Jholmol (26.47%). Emamectin benzoate (21.73%) and Azadirachtin (22.07%) were statistically similar in terms of leaf infestation. But at 12 days after the first spray, the least leaves infestation was recorded in Chlorantraniliprole (11.29%), which was statistically at par with Spinosad (13.49%), and the most infested leaves were recorded in Control (water spray) (32.43%). At 6 days after the second spray, the least infested leaves were recorded in the Chlorantraniliprole (11%) sprayed plot, which was at par with Spinosad (14.31%). Similarly, the highest levels of leaf damage were recorded in Control (water spray) (33.58%) plots. Similar results were recorded at12 days after the second spray, with the lowest infestation in Chlorantraniliprole (6.59%) followed by Spinosad (8.36%), and the highest infestation was in the Control (water spray) (33.69%) plot

(Table 2).

Table 2

Percentage of infested leaves on after first and second spray in Kapurkot, Salyan, 2021

Treatments	Leaves infestation (%)			
	First Spray		Second Spray	
	6 DAS	12 DAS	6 DAS	12 DAS
Emamectin benzoate	21.73^{bc} (4.66)	21.97^{c} (4.68)	20.90^{c} (4.54)	13.48^{cd} (3.63)
Jholmol	26.47^{ab} (5.14)	28.71^{ab} (5.35)	28.76^{ab} (5.36)	22.43^{b} (4.66)
Spinosad	11.77^{d} (3.42)	13.49^{d} (3.65)	14.31^{d} (3.75)	8.36^{e} (2.87)
Azadirachtin	22.07^{bc} (4.60)	23.97^{bc} (4.89)	26.90^{b} (5.19)	19.88^{bc} (4.44)
Imidacloprid	18.76^{c} (4.32)	21.15^{c} (4.59)	24.47^{bc} (4.94)	13.41^{cd} (3.65)
Chlorantraniliprole	13.18^{d} (3.62)	11.29^{d} (3.35)	11.00^{d} (3.30)	6.59^{e} (2.53)
Control (water spray)	31.56^{a} (5.61)	32.43^{a} (5.69)	33.58^{a} (5.79)	33.69^{a} (5.80)
LSD(0.05)	0.58	0.64	0.56	0.89
F test	***	***	***	***
SEm(±)	0.19	0.21	0.18	0.28
CV(%)	7.34	7.86	6.79	12.69

SEM (±) is the standard error of the mean, CV is the coefficient of variation, LSD is the Least significant difference, and treatment means with the same letter do not differ significantly at $p \leq 0.05$ by DMRT. The figures in the parentheses are the square-root transformed values. *** highly significant at $p \leq 0.001$

The percentage of infested fruits by *T. absoluta* was influenced by the application of all treatments and all days (Table 3). At 6 DAS, the lowest infestation was recorded in Chlorantraniliprole (6.58%) sprayed plots. Similarly, the highest infestation of fruits was recorded in the Control (water spray) (18.59%) plot, which was statistically similar to Jholmol (17.31%). Imidacloprid (12.49%), Emamectin benzoate (12.33%), and Azadirachtin (13.79%) were statistically similar in terms of percentage fruit damage. At 12DAS, the least infested fruits were recorded in Chlorantraniliprole (1.88%), which was at par with Spinosad (3.79%), and the highest infestation of fruits were found in Control

(11.97%) (water spray) with was significantly similar with the Jholmol (10.43%) and Azadirachtin (9.33%) sprayed plots. At 6 days after the second spray, the least infested fruits were recorded in Chlorantraniliprole (2.00%) sprayed plots which was at par with Spinosad (3.80%). Similarly, the highest fruit damage was recorded in Control (water spray) (12.09%). Similar results were also observed in 12 days after the second spray, with the lowest infestation found with Chlorantraniliprole (0.45%), Spinosad (2.24%), and the highest infestation found in Control (water spray) (10.26%) (Table 3). Bajracharya et al. (2016) in their study reported that fruit and leave infestation was the lowest in the Chlorantraniliprole and Spinosad sprayed fields.

Table 3

Percentage of infested fruits after first and second spray in Kapurkot, Salyan, 2021

Treatments	fruit infestation (%)			
	First Spray		Second Spray	
	6 DAS	12 DAS	6 DAS	12 DAS
Emamectin Benzoate	12.33^{bc} (3.57)	5.48^{c} (2.42)	5.63^{cd} (2.44)	4.06^{bc} (2.13)
Jholmol	17.31^{a} (4.21)	10.43^{a} (3.27)	8.56^{abc} (3.00)	6.82^{ab} (2.69)
Spinosad	9.62^{c} (3.18)	3.79^{cd} (2.06)	3.80^{de} (2.06)	2.24^{c} (1.65)
Azadirachtin	13.79^{b} (3.77)	9.33^{a} (3.13)	9.43^{ab} (3.15)	3.41^{c} (1.90)
Imidacloprid	12.49^{bc} (3.60)	5.91^{bc} (2.52)	7.43^{bc} (2.80)	4.14^{bc} (2.06)
Chlorantraniliprole	6.58^{d} (2.65)	1.88^{d} (1.53)	2.00^{e} (1.57)	0.45^{d} (0.94)
Control(Water Spray)	18.59^{a} (4.36)	11.97^{a} (3.50)	12.09^{a} (3.52)	10.26^{a} (3.26)
LSD(0.05)	0.413	0.667	0.585	0.683
F test	***	***	***	***
SEm(±)	0.134	0.216	0.189	0.222
CV (%)	6.41	14.20	12.39	18.34

SEM (±) is the standard error of the mean, CV is the coefficient of variation, LSD is the Least significant difference, and treatment means with the same letter do not differ significantly at $p \leq 0.05$ by DMRT. The figures in the parentheses are the square-root transformed values. *** highly significant at $p \leq 0.001$

The marketable yield of tomatoes in all experiment plots was influenced by the application of insecticides (Figure 1). The highest marketable yield was obtained in Chlorantraniliprole (85.26 t/ha), followed by Spinosad (79.26 t/ha), both are significantly similar. The marketable yield in other treatments such as Emamectin benzoate; Azadirachtin, Imidacloprid; and Jholmol sprayed plots were 75.13 t/ha, 74.1 t/ha; 72.06 t/ha, and 71.2 t/ha, respectively. The lowest marketable yield was obtained in control plots which was 64.46 t/h (Figure 1).

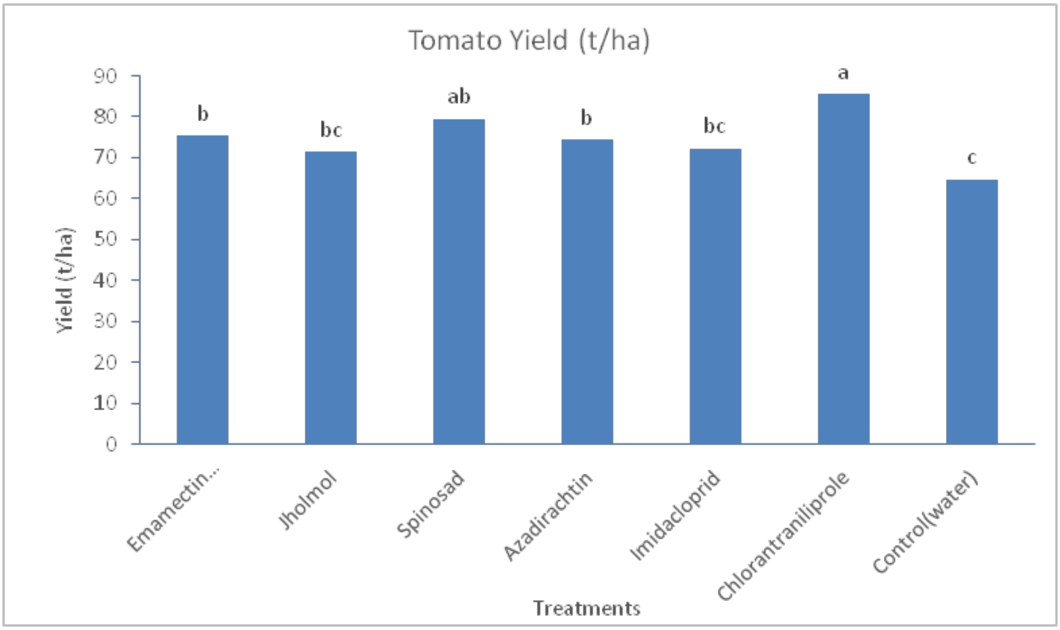
Chlorantraniliprole is a synthetic chemical product that kills insects mainly by stomach action. It is extremely effective against the lepidopteran species followed by Coleoptera and Diptera insect species. Larraín et al., (2014) and Sapkota et al., (2018) in their study reported that the Chlorantraniliprole sprayed tomato field had the lowest percentage of leaf and fruit damage by *T. absoluta* as compared to the other tested chemicals.

Similarly, Spinosad is derived from the naturally occurring actinomycetes, *Saccharopolyspora spinosa* (Sparks et al., 1998). Because of its unique mode of action involving the postsynaptic nicotinic acetylcholine and Gamma-aminobutyric (GABA) receptors, Spinosad has strong insecticidal activity (Salgado, 1998), especially against Lepidoptera larvae (Méndez et al., 2002; Wang et al., 2009). Spinosad is a widely recommended pesticide for other lepidopteran species in Nepal such as fall armyworm (*Spodotera frugiperda*), Tomato fruit borer (*Helicoverpa armigera*), Maize stem borer (*Chilo partellus*), and many other lepidopteran insects. Spinosad's use against this species in introduced areas should be carefully monitored to prevent rapid selection for high levels of resistance and the potential for its spread to new areas. (Ribeiro de Campos et al., 2014).

Nowdays, neem-based insecticides are popular in farming communities since they are comparatively safer for human health and pollinators (Benelli et al., 2017). Azadirachtin, a tetranortriterpenoid isolated from neem tree seeds, *Azadirachta indica* (Meliaceae), and chinaberry fruit, *Melia azaderach* (Meliaceae), acts as an antifeedant and inhibits the growth and development of several insects (Raffa, 1987). However, chemical insecticides such as Chlorantraniliprole, Spinosad, and Emamectin benzoate are more efficient than plant-based insecticides.

Figure 1

Effect of different insecticides on the marketable yield (t/ha) of tomato, Kapurkot, Salyan, 2021



Conclusion

Tuta absoluta is a major invasive and destructive pest of tomatoes in many tomato-growing countries in the world including Nepal. Agroecological and organic strategies are recommended for sustainable farming. Since chemical-based farming increases pest resistance and other negative effects to the environment and biodiversity. There is a blanket recommendation of chemical pesticides by the pesticide dealer to control the wider group of insects. These recommendation practices to all circumstances are not applicable and useful. Therefore, there should be regular observation of pesticides to check their effectiveness to the target insect pest. In this study, various market-available synthetic chemical insecticides including some botanically based pesticides were tested in the open field to evaluate their efficiency for the tomato leaf miner. Chemical insecticides such as Chlorantraniliprole, Spinosad, and Emamectin benzoate were superior to the other safe plant-based biopesticides. The highest marketable yield was obtained in plots treated with Chlorantraniliprole, followed by Spinosad and Emamectin benzoate. Nevertheless, chemicals can have the side effect of destroying beneficial natural enemies and can lead to the development of insecticide resistance. For these reasons, it is essential to devise a management program against *T. absoluta* by the rotation of effective insecticides with different modes of action and encourage the use of alternative pest management strategies including cultural, mass-trapping, and biological control through an integrated pest management program. In summary, agroecological pest management practices should be the priority of pest management followed by mechanical, physical, biological, and finally safe chemicals. All market-available insecticides are not equally effective hence their effectiveness should be tested before recommendation to the farmers.

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Conflict of Interest

The authors have no relevant financial or non-financial interests to disclose.

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