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Research Article

EFFICACY OF NOVEL INSECTICIDES AGAINST SOUTH AMERICAN TOMATO LEAF MINER (*Tuta absoluta* MEYRICK*)* UNDER PLASTIC HOUSE CONDITION IN KATHMANDU, NEPAL

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ABSTRACT

The South American tomato pinworm *Tuta absoluta* introduction in Nepal is rather recent. Despite its recent introduction, it has become a major economical pest of both outdoor and plastic house tomatoes in various localities of Nepal. The yield and quality of tomato crops will be reduced by the steady feeding of *Tuta absoluta.* Under this context a study was done to determine the efficacy of novel insecticides against *Tuta absoluta*. Eight treatments viz; (Chlorantraniliprole @ 0.3 ml/l; Imidacloprid @ 0.6 ml/l; Abamectin @ 0.5ml/l; *Bacillus thuringenesis* (Bt) var. kurstaki @ 2 g/l; Azadiractin @ 5ml/l; Spinosad @ 0.3 ml/l; mixture of Abamectin + Bt @ 2.5 ml/l; and control) were tested against *Tuta absoluta* in plastic house grown tomatoes in Tarkeshwor, Kathmandu. Chlorantraniliprole spray results significantly lower number of mines per leaf (0.10 mines per leaf) at count after seven days of second spray. Effectiveness of pesticides followed the same trend, monitored after 7 days of subsequent spray. The effect of insecticides at 7 days after first application was such that Spinosad had the best results in reducing the number of *Tuta absouta* larvae count on terminal buds (0.11 larvae/terminal buds) followed by statistically similar effect of Chlorantraniliprole (0.14 larvae/terminal buds). Chlorantraniliprole was the most effective to minimize the infestation of *Tuta absoluta* in tomatoes.

Key words: *Lycopersicon esculentum, Tuta absoluta,* chlorantraniliprole, spinosad

INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill), is one of the most consumed vegetables in the world. Tomato production can improve economic status of both the commercial and peri-urban farmers as it is the vegetable with high per capita consumtion rate in Nepal. It is being successfully produced during off-season, its cultivation in plastic house in the hills ensuring uniform stand of tomato all the year round. The total productivity of tomato in Nepal is about 331736 t from 19725 hectares of land with productivity17 t/h (MOAD, 2016).

Productivity of tomato in Nepal is lower than half by the world average due to several factors. Seasonal weather, temperature, humidity, diseases and insect pests are the notable constraint for disappointing fruit quality and decreased tomato production.

Global agriculture and trade introduced new pests into the country frequently. The South American tomato pinworm *Tuta absoluta* introduction in Nepal is rather recent. It was reported for the first time, from Kavrasthali in Kathmandu valley of Nepal in 2016 (Bajracharya et al., 2016) and then distributed to most parts of the country. Despite its recent introduction, it has become a major economical pest of both outdoor and plastic house tomatoes in various localities of Nepal. The yield and quality of tomato crops will be reduce by the steady feeding of *Tuta absoluta*, the punctures on the tomato fruit made by this insect makes the ingress of secondary pathogens more easier (Kaoud, 2014). The pest wiped out tomato plantations, causing 100 % crop loss for some producers. Furthermore, the mine-feeding nature of the larvae helps them to escape from direct contact with pesticides. The invasion would ultimately result in large environmental and economic issues. For the proper development of *Tuta absoluta* management scheme, novel and safe insecticides should be applied as an alternative to harsh synthetic insecticides and also due to its little mammalian toxicity, low endurance in the environment, and bio-degradability (EPPO, 2005). The main objective of this research was to determine the efficacy of novel insecticides against *Tuta absoluta* on plastic house grown tomatoes.

MATERIALS AND METHODS

Kavrasthali, Tarakeshwor-9, Kathmandu where plastic house tomato cultivation is predominant was purposively chosen for the study, which is at the geographical coordinate of 27˚44.661'N latitude and 85˚18.895'E longitude with an altitude of 1314 masl. The size of the plastic house was 60 sq. m (6mX10m) and the height of the plastic house was maintained as 3.5m. A total of 18 plants per plot, plant spacing was maintained as 55 cm plant to plant and 75cm row to row. Only one variety Shrijana was planted. The effectiveness of plant protection products for *Tuta absoluta* was tested. For this population dynamics was monitored before and after treatment under plastic house. The experiment was carried out using a Randomized Complete Block Design (RCBD) with eight treatments, each replicated three times, considering one farmer as one replication.

The first monitoring was done one day before first spray. Periodic observations were taken before the treatment and in intervals 3rd and 7th day of both first and second spray of treatments respectively. To assess the *T. absoluta* infestation prior to the trial, terminal buds were examined under magnifier and *T. absoluta* larvae were counted just before insecticide spray and after post-treatments. The means of the number of *Tuta absoluta* infested fruits with galleries, galleries per fruit, number of live larvae in terminal buds and larvae mines per leaf was recorded before and after treatments and was compared. This observation was taken from 5 randomly selected plants per treatment per replication. The plant protection products used with their active ingredients, the trade name, chemical group, and doses are given in Table (1). The products were diluted with tap water; the volume of the spray solution was maintained @ 3-4 l/plot. The spray solution of the pesticide was applied directing on the canopy of the tomato plants.

Table 1. Insecticides compounds experimented under plastic house tomato, 2017

Common Name	Trade Name	Active ingredient %	Formulation type	Dose	Chemical Group
Chlorantraniliprole	Coragen	18.5	SC	0.3 mL/ L	Ryanodine
Imidacloprid	Sumo	17.8	SL	0.6 mL/ L	Neonicotinoid
Abamectin	Vertimic	1.9	EC	0.5mL/L	Evermectin
BacillusThuringenesis (Bt) var. kurstaki	Dipel		WP	2 g/ L	Microbial
Azadiractin 300 ppm	Niconeem	1	EC	5mL/L	Botanical
Spinosad	Tracer	45	SC	0.3 mL/ L	Spinosyn

All data recorded from the field experiment were tabulated and drawn in the Microsoft Excel. Before analysis, all field experiment data were tested for normality test and the data were log transformed. The data were analyzed with analysis of variance based on generalized linear model procedure SAS 9.4 (Proc glm). Wherever significant difference occurred; Tukey's hsd test was applied for mean separation. The percentages of efficacies of insecticides were evaluated using.

Abbott formula: the percentage of efficacy = (Ca-Ta)/Ca×100 where

Ca is the average live larvae in the control and
Ta is the mean survival score in the treatment.

RESULTS AND DISCUSSION

Monitoring of *Tuta absoluta* mines/leaf in plastic house tomato before and after treatments

Three days following the first application, all the products performed well, except Imidacloprid and *Bacillius thurigenesis* that remained statistically similar (p>0.05) compared to the control (Table 2). All the tested products almost reduced the density of mines per leaf compared with the control (F= 4.66; SE=0.03; p= 0.0051). At first spray, the most effective insecticide was found as Azadiractin which resulted fewest number of mines per leaf (0.22 mines per leaf) that was followed by Chlorantraniliprole in terms of its effect (0.26 mines per leaf). After seven days of first spray, both Azadiractin and chorantraniliprole had very good response in terms of reducing number of mines in tomato leaves followed by the use of spinosad. However, spray of Imidacloprid remained feeble.

Like in the case of first spray, effect of insecticide spray was significantly different (p<.0001) to the number of mines per leaf at three and seven days following the second application. In case of second spray, all the tested products performed well (F= 18.54, SE=0.09; p <.0001). Chlorantraniliprole spray resulted significantly lower number of mines per leaf (0.10 mines per leaf) at count after seven days of second spray, that remained statistically similar (p>0.05) to Spinosad, Abamectin+Bt, and Azadarictin spray for number of mines per leaf. *Bacillus thuringiensis,* spinosad and azadirachtin were among the largely admired bio-rationale insecticides used for dominating large number of insect pests (Merdan et al., 2010; Braham et al., 2012). Many authors consider underlying property and value of neem extract as an effective insecticide due to its anti-feedant and repellent activities against their aimed insect (Isman 2006; Hiiesaar et al., 2009).

Table 2. Mean number of mines/ leaf on indicated days against *Tuta absoluta* at first spray in plastic house tomato in Kavrasthai, Kathmandu, 2017

Insecticides	0DB1T	3DA1T	7DA1T	3DA2T	7DA2T
Spinosad	0.73 ab	0.37 c	0.36 bcd	0.13 cd	0.17 c
Control	0.61 ab	0.67 a	0.64 ab	0.72 a	0.72 a
Abamectin	0.66 ab	0.49 abc	0.38 bcd	0.35 bc	0.35 bc
Azadiractin	0.56 b	0.41bc	0.22 d	0.29 bc	0.14 c
Abamectin+Bt	0.73 ab	0.54 abc	0.50 abcd	0.26 bcd	0.17 c
Imidachloropid	0.70 ab	0.67 a	0.74 a	0.63 a	0.67 a
Chlorantraniliprole	0.53 b	0.35 c	0.26 cd	0.00 d	0.10 c
Bacillius thurigenesis	0.80 a	0.61 ab	0.60 abc	0.45 ab	0.47 ab
F value	4.66	7.49	6.88	18.01	18.54
Variance	0.01	0.02	0.03	0.06	0.06
SE	0.03	0.05	0.07	0.09	0.09
R square	0.67	0.76	0.75	0.88	0.89
P	0.0051	0.0004	0.0007	<.0001	<.0001

Means followed by the same letter within a column are not significantly different at P= 0.05 (ANOVA-GLM procedure) followed by Tukey multiple comparison.

0DB1T= 1 Day before first treatment
DA1T= Days after first treatment
DA2T= Days after second treatment

Monitoring of *tuta absoluta* mines/fruit in plastic house tomato before and after treatments

The effect of pesticide one day before treatment was not significant (p>0.05), and also uniformity on mines per fruit was noted even after three days of the first application. Nevertheless, minimum number of mines per fruit was recorded with Chlorantraniliprole spray which was statistically different (p<0.05) with all other treatment tested (Table 3). Seven days following the first application, all the compounds performed well with lowest mines per fruit in Chlorantraniliprole treated plot (0.11 mines/fruit) followed by Azadarictin and Abamectin+*Bt* (0.27 mines/fruit); both being statistically similar (p>0.05). After three days following the second application, the mean number of mines per fruit was varied significantly (p<0.05) between treated and control plots (F= 5.43; SE=0.06; p= 0.0025).

The efficacy of all the tested products remains high compared with the control. Nevertheless, Chlorantraniliprole (Coragen) tend to be a powerful suppressor of larvae of *Tuta absoluta* thereby reducing the mean number of mines per fruit from 0.21 to 0 after three days of second spray (Table 3). After seven days of second spray, both Chlorantraniliprole and Abamectin+ Bt treated plants which were statistically similar (p>0.05), resulted in no mines per fruit. Though statistically different from Chlorantraniliprole and Abamectin+Bt, Spinosad also had better performance (0.15 mines per fruit). Like in the case of other parameters, Imidacloprid was again the least effective pesticide resulting highest number of mines per fruit (0.50) which was followed by control (0.58 mines/fruit). Similar results were recorded by Hilal and Oktay (2006), as the authors reported that spinosad was very effective in controlling lepidopteran pest; *Spodoptera* *littoralis*. Maraus et al. (2008) also reported Spinosad as standard product for the management of *Tuta absoluta* in Brazil.

Table 3. Mean number of mines/ fruit on indicated days before treatment and after treatment against *Tuta absoluta* in plastic house tomato in Kavrasthai, Kathmandu, 2017

Insecticides	0DB1T	3DA1T	7DA1T	3DA2T	7DA2T
Spinosad	0.50	0.48 a	0.31 abc	0.20 abc	0.15 bc
Control	0.44	0.56 a	0.56 a	0.53 a	0.58a
Abamectin	0.43	0.37 a	0.38 abc	0.28 abc	0.25 abc
Azadiractin	0.48	0.39 a	0.27 bc	0.27abc	0.14 bc
Abamectin+Bt	0.46	0.44 a	0.27 bc	0.15 bc	0.00 c
Imidachloropid	0.39	0.46 a	0.51 ab	0.50 ab	0.50 ab
Chlorantraniliprole	0.21	0.09 b	0.11 c	0.00 c	0.00 c
Bacillius thurigenesis	0.52	0.41 a	0.39 abc	0.27 abc	0.26 abc
F value	2.19ns	5.86	5.95	5.43	6.24
Variance	0.01	0.02	0.02	0.03	0.04
SE	0.03	0.05	0.05	0.06	0.07
R square	0.48	0.71	0.72	0.70	0.73
P	0.0925	0.0017	0.0015	0.0025	0.0012

Means followed by the same letter within a column are not significantly different at p= 0.05 (ANOVA-GLM procedure) followed by Tukey multiple comparison.
^{ns}non-significant at 5 % (p>0.05)

Monitoring of *tuta absoluta* fruits with galleries /plant in plastic house tomato before and after treatments

At three days, following the first application, the mean number of fruit with galleries did not vary significantly (p>0.05) between treated and control plots (GLM-ANOVA Procedure, p=0.13). Nevertheless, plants treated with the product Chlorantraniliprole harbor least number of fruit with galleries suggesting the good efficacy of this insecticide. Likewise, 7 days after the first spray, Chlorantraniliprole was more distinct in reducing number of fruit with galleries/plant whereas some of the treatments such as Imidacloprid were non-responsive to have such effect (Table 4). Besides chlorantraniliprole treatments like Spinosad, Azadiractin and Abamectin+ Bt was comparatively well responsive in terms of reducing the number of fruit with galleries/plant. At 3 and 7 days following the second pesticide application, all tested insecticides continue to be effective compared with the control (F= 4.52 SE=0.06, p= 0.0059) (F=20.43; SE=0.09, p <.0001) respectively. Treatment Abamectin+ Bt shows the highest efficiency in reducing the number of fruits with galleries from before spray to 7th day of second spray (Table 4) which was followed by the efficacy of statistically similar Spinosad, Azadiractin and Chlorantraniliprole spray. Imidagold spray resulted no significant difference (0.54 before spray to 0.49 fruit with galleries at 7th day of second treatment application), but remained statistically different (p<0.05) to the effect of control. Abamectin spray was mild effective in reducing the number of fruit with galleries per plant that remained statistically similar (p>0.05) to the effect of *Bacillus thuringenesis* spray (Table 4). The new mode of action of Chlorantraniliprole may be the possible reason behind its success in managing resistant insect species.

Table 4. Mean number of fruits with galleries on indicated days before treatment and after treatment against *Tuta absoluta* in plastic house tomato in Kavrasthai, Kathmandu, 2017

Insecticides	0DB1T	3DA1T	7DA1T	3DA2T	7DA2T
Spinosad	0.44	0.40	0.23 ab	0.23 abc	0.12 cd
Control	0.46	0.52	0.50 a	0.55 a	0.71 a
Abamectin	0.57	0.51	0.46 a	0.29 abc	0.21 bc
Azadiractin	0.56	0.48	0.31 ab	0.24 abc	0.05 cd
Abamectin+Bt	0.51	0.42	0.34 ab	0.11 bc	-0.11 d
Imidachloropid	0.54	0.49	0.54 a	0.44 ab	0.49 ab
Chlorantraniliprole	0.41	0.28	0.04 b	0.04 c	0.03 cd
Bacillius thurigenesis	0.55	0.42	0.35 ab	0.24 abc	0.25 bc
F value	1.21ns	1.90ns	4.52	4.52	20.43
Variance	0.00	0.01	0.03	0.03	0.07
SE	0.02	0.03	0.06	0.06	0.09
R square	0.34	0.45	0.66	0.66	0.89
P	0.3501	0.1366	0.0059	0.0059	<.0001

Means followed by the same letter within a column are not significantly different at P= 0.05 (ANOVA-GLM procedure) followed by Tukey multiple comparison
[ns]non-significant at 5 % (P>0.05)

Monitoring of *tuta absoluta* live larvae on terminal buds in plastic house tomato before and after treatments

At 3 days after the first treatment applications, there was a significant difference between treatments (p<0.05) regarding the mean number of live larvae on terminal buds (AVOVA-GLM procedure, p= 0.0008, Table 5). Seven days following the first application, the mean number of larvae per terminal buds was significantly different (p<0.05) between treated and control plots (ANOVA-GLM procedure p= 0.0003). The effect of insecticides at 7 days after first application was such that Spinosad had the best results in reducing the number of *Tuta absouta* larvae count (0.11 larvae/terminal buds) followed by statistically similar effect of Chlorantraniliprole (0.14 larvae/terminal buds). Azadiractin showed the mild efficacy (0.19 larvae/terminal buds). On the other hand, effect of Imidacloprid was least effective resulting highest number (0.68 larvae per terminal buds) which was statistically similar (P=0.0008) to the effect of control (0.62 larvae/terminal buds) followed by Bt spray (0.53 larvae/terminal buds).

Likewise, after the second spray, the effectiveness of treatments followed the same pattern as in the case of first spray. Seven days after the second spray, the treated plots were highly significant (ANOVA-GLM procedure p<.0001) against the control, showing the good performance of the compounds; Spinosad, Chlorantraniliprole, and mixture of Abamectin+*Bt*. Whereas in both third and seventh day of second spray, the low level of effectiveness was observed in the case of Imidacloprid, resulting higher number of larvae per terminal buds (0.68) which was statistically similar (p>0.05) to that of the control plot (0.71 larvae/terminal bud, Table 5). Imidacloprid had low toxicity effect in terms of reducing larval population of *Tuta absoluta*. This may be due to longer history of the use of neonics compounds in plastic house and open fields.

Table 5. Mean number of total live larvae on terminal buds on indicated days before treatment and after treatment against *Tuta absoluta* in plastic house tomato in Kavrasthai, Kathmandu, 2017

Insecticides	0DB1T	3DA1T	7DA1T	3DA2T	7DA2T
Spinosad	0.70	0.23bc (56.92)	0.11 c (64.52)	-0.08 cd (78.87)	-0.10 cd (83.12)
Control	0.54	0.64 a	0.62 a	0.67 a	0.71 a
Abamectin	0.62	0.49 abc (26.15)	0.42 abc (32.26)	0.23 abc (61.97)	0.27 bc (62.34)
Azadiractin	0.48	0.29 abc (53.85)	0.19 bc (61.29)	0.10 bcd (71.83)	0.03 cd (79.22)
Abamectin+Bt	0.66	0.23 bc (60.00)	0.35 abc (45.16)	0.05 bcd (74.65)	-0.24 d (88.31)
Imidachloropid	0.58	0.61 a (4.62)	0.68 a (-16.13)	0.56 ab (21.13)	0.68a (6.49)
Chlorantraniliprole	0.67	0.16c (66.15)	0.14c (66.13)	-0.30d (88.73)	-0.28d (89.61)
Bacillius thurigenesis	0.76	0.54 ab (20.00)	0.53ab (17.74)	0.39abc (47.89)	0.39 ab (50.65)
F value	2.17	6.72	8.09	9.81	28.17
Variance	0.01	0.04	0.05	0.11	0.15
SE	0.03	0.07	0.08	0.12	0.14
R square	0.48	0.74	0.77	0.81	0.92
P	0.0951	0.0008	0.0003	<.0001	<.0001

Means followed by the same letter within a column are not significantly different at P= 0.05 (ANOVA-GLM procedure) followed by Tukey multiple comparison
* Data in brackets denote Abbott mortality (Abbott, 1925)

Effect of insecticides in reducing live larvae on terminal buds in plastic house tomato before and after treatments

The graph representing overall efficacy (Abbott formula, 1925) shows the good performance of Chlorantraniliprole (coragen), the mixture of Abamectin+ Bt and spinosad (Tracer) throughout the experiments (Figure 1). Chlorantraniliprole was the most powerful treatment (66.15%) after 3 days of first spray followed by the mixture of Abamectin + Bt (60%), and Spinosad (57%)) efficacy. Abamectin, *Bacillus thuringensis* and Imidacoprid had their effectiveness as 26%, 20% and 5%; significantly inferior in efficacy against *T. absoluta* within first three days of application, respectively. Three days following the second insecticide application, all tested compounds showed the high effectiveness. Chlorantraniliprole performed very well (89%). Almost all insecticides had resulted the mean percent reduction of *T. absoluta* and were significantly higher than control treatments. Sometimes, however, potency of Imidacloprid was almost similar to that of the control.

Sansinenea (2012) reported one of the drawbacks of *Bacillus thuringienesis* –as it could be very difficult to transport to the pests that are inside plant tissues. On the other hand, abamectin can permeate the internal leaves and kill the leaf larvae that hide in the internal leaves and also prevent the newborn larvae from sneaking into the leaves (http://plantchemical.com). May be combination of these two types of mode of action complimented resulting in higher larvicidal action. It can be speculated that Bt may have hit the stressed larval population due to abamectin making them more vulnerable. Compared with the other products tested, Imidacloprid had low toxicity effect in terms of reducing larval population of *Tuta absoluta* in terminal buds of tomato. Sallam et al. (2015) reported Imidacloprid as the least effective insecticide against *Tuta absoluta* larvae. This was truly reflected in this study as Imidacloprid was counterproductive in lowering the number of *Tuta absoluta* larval population and affected tomato leaves and fruit.

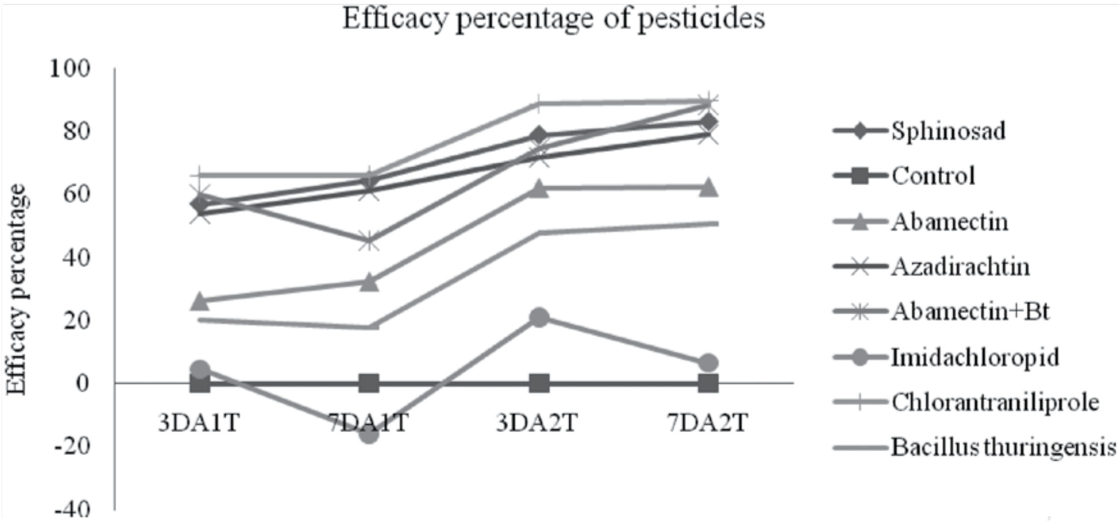

Fig 1. Overall percentage of different insecticide efficacy on mean number of larvae/terminal buds on indicated days after treatment (DAT) according to Abbott formula (1925)

CONCLUSION

Large host range and innate ecology of *T. absoluta* has made this a crucial pest of tomato around the world. The results obtained in this study demonstrated that Chlorantraniliprole was the most effective in managing *Tuta absoluta* whereas Spinosad and Abamectin and *B. thuringiensis* combination was also equally effective.

Since this experiment uses multiple insecticides with different modes of action and most of it provides good-to-excellent control, tomato growers have the advantage of practical choices for the management of *Tuta absoluta* based on their interest and use of other integrated pest management measures.

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