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Population dynamics and management of citrus leaf miner, *Phyllocnistis citrella* (Stainton) in nursery

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Abstract
The investigation examined the effectiveness of various insecticide modules against citrus leaf miner infestation in a citrus nursery. These modules included Azadirachtin 1500 ppm combined with different chemical agents. Incidence of citrus leaf miner on Nagpur mandarin seedlings commenced in the 36th meteorological week at 14.96% infestation, peaked at 70.25% in the 42nd week, and subsequently declined. Infestation was notably higher in newly sprouted leaves during the 41st and 42nd weeks, showing significant positive correlation with evaporation and non-significant positive correlation with high temperature, and negative correlation with low temperature, morning and evening relative humidity, and rainfall. The cumulative effect of three applications across all modules revealed that Module-2 (Azadirachtin 1500 ppm combined with Thiamethoxam 25 WP and Thiamethoxam (12.6%) + Lambdacyhalothrin (9.5%) ZC) exhibited the lowest leaf infestation rate at 13.73%, significantly superior to the control. Module-7 followed with 14.18% leaf infestation. Modules 1, 4, and 6 were also effective, recording leaf infestation rates of 15.15%, 15.60%, and 15.62%, respectively. Module-5 recorded the highest infestation rate at 18.56%, while the control (water spray) exhibited a maximum infestation rate of 27.43%.

Keywords: *Citrus reticulate*, *Citrus psylla*, applications

Introduction
Citrus cultivation holds significant global economic importance, encompassing various species such as orange, sweet orange, acid lime, and related variants. Originating from citrus belts in California and tropical regions of India in the 18th century, citrus fruit production ranks as the third-largest food industry in India's agricultural sector, contributing substantially to the nation's economy. Specifically, Nagpur Mandarin (*Citrus reticulata*) stands out for its exceptional taste, flavor, and aroma. In India, citrus cultivation covers approximately 1023.54 thousand hectares, yielding a production of 11580.76 thousand MT, occupying 14.93% of the total fruit area and contributing 12.52% to the overall fruit production, with a productivity rate of 9.1 MT/hectare (Anonymous, 2018b) [4].

Among Indian states, Maharashtra ranks second in citrus fruit production, contributing 15.79% of the total output. With an area of 275.0 thousand hectares dedicated to citrus cultivation, Maharashtra yields 1761.0 thousand MT of citrus fruit, with a productivity rate of 5.57 MT/ha (Anonymous, 2018a) [3]. Notably, districts like Nagpur, Amravati, Akola, and Wardha in the Vidarbha region of Maharashtra lead in citrus production. Nagpur Mandarin, renowned globally, dominates citrus cultivation in this region, earning Nagpur the moniker "Orange City."

Citrus leaf miner, a significant pest affecting citrus plants in nurseries and orchards, has been observed in various countries, including India (Atwal, 1964). In Maharashtra, during April 1981, the pest caused damage as high as 87.41% in Warud taluka of Amravati district, with citrus leaf miner alone contributing to 30% of the total damage inflicted by the citrus pest complex (Ghuguskar *et al*., 1981) [10].

The citrus leaf miner (*Phyllocnistis citrella*) is a small lepidopteron pest that inflicts damage during its larval stage by creating mines in immature foliage. Severe infestation leads to twisted and curled leaves, thereby affecting the growth and yield of nursery and newly planted trees. Although less severe on mature trees, it remains a concern. The pest typically peaks in summer and autumn, with about 5-6 generations per year and a high migration ability. Control measures are challenged by its protective mining behavior, necessitating evaluations of various

insecticides, including botanicals and chemicals (Achor *et al*., 1996; Pena *et al*., 1996; Belasque *et al*., 2005) [1, 18, 8].
In the Vidarbha region, citrus leaf miner poses a serious threat to nurseries and established orchards, with infestations observed as high as 54.7%, 52%, and 43.4% in spring, monsoon, and autumn, respectively (Shivankar and Rao, 2003a) [23]. Despite efforts involving bioagents, effective control remains elusive, impacting citrus quality and quantity. Thus, timely application of chemical insecticides during the pest's sensitive stages, coupled with population dynamics correlated with weather parameters, emerges as a crucial strategy in citrus pest management.

Materials and Methods

Experimental Details

The investigation was carried out by the Entomology and Horticulture Sections of the College of Agriculture, Nagpur, with oversight from the Professor of Horticulture and In-charge of the Centre of Excellence for Citrus. The experimental design for this study utilized a Randomized Block Design (RBD), consisting of three replications and eight treatments across a total of 24 plots. Each plot contained 12 nursery plants of the Nagpur mandarin variety, with five plants selected for observation per block. The distance between replications was maintained at 1.0 meter, ensuring adequate spatial separation. All plants involved in the study were aged at 7 months. This design aimed to provide a systematic framework for evaluating the performance and characteristics of the Nagpur mandarin variety under controlled conditions. List of details of module of insecticides used in experiments given in the table 1.

Table 1: Details of module of insecticides used in experiments

Module No.	Module details
1	Azadirachtin 1500 ppm @ 3.0 ml/lit. fb Thiamethoxam 25 WP @ 2.5 gm/lit fb Chloratraniliprole (10%) +Lambda cyhalothrin (5%) ZC @ 1.5 ml/lit.
2	Azadirachtin 1500 ppm @ 3.0 ml/lit. fb Thiamethoxam 25 WP @ 2.5 gm/lit fb Thiamethoxam (12.6%) +Lambdacyhalothrin (9.5%) ZC @ 0.5 ml/lit.
3	Azadirachtin 1500 ppm @ 3.0 ml/lit. fb Thiamethoxam 25 WP @ 2.5 gm/lit fb Profenofos (40%) + Cypermethrin (4%) EC @ 2.0 ml/lit.
4	Azadirachtin 1500 ppm @ 3.0 ml/lit. fb Imidacloprid 17.8 SL @ 1.06 ml/lit. fb Chloratraniliprole (10%) +Lambdacyhalothrin (5%) ZC @ 1.5 ml/lit.
5	Azadirachtin 1500 ppm @ 3.0 ml/lit. fb Imidacloprid 17.8 SL @ 1.06 ml/lit. fb Profenofos (40%) +Cypermethrin (4%) EC @ 2.0 ml/lit.
6	Azadirachtin 1500 ppm @ 3.0 ml/lit. fb Diflubenzuron 25 WP @ 3.2 gm/lit. fb Thiamethoxam (12.6%) +Lambdacyhalothrin (9.5%) ZC @ 0.5 ml/lit.
7	Azadirachtin 1500 ppm @ 3.0 ml/lit. fb Diflubenzuron 25 WP 3.2 gm/lit. fb Profenofos (40%) + Cypermethrin (4%) EC @ 2.0 ml/lit.
8	Control (water spray).

Method of application of insecticides

Method of application

Spraying of the insecticides, were performed with the help of Ganesh pump sprayer and the plants were treated with enough care to cover whole of the plant surface, due care was also taken to avoid drifting of spray material from one treatment block to another. Spraying was conducted during morning hours. Approximately one-liter spray solution was prepared every time for spraying three blocks of each treatment.

Time of application of treatment

Upon the detection of leaf miner infestation on citrus nursery plants, spraying commenced, totaling three applications. Observations were systematically recorded before 24 hours and after the 7th and 14th days following each application. The first application took place on 04/09/2019, followed by the second on 20/09/2019, and the third on 10/10/2019.

Method of recording observation

The methods employed for observing citrus leaf miner in this investigation involved weekly assessments of leaf miner incidence on five randomly selected Nagpur mandarin grafts. Total leaves and infested leaves were tallied on each selected graft to calculate the percentage of leaves affected by the citrus leaf miner. Pre-treatment observations were conducted within 24 hours before treatment application, while post-treatment observations were carried out on the 7th and 14th days following treatment. Total leaves and infected leaves were counted on randomly selected seedlings to determine the percentage of leaves infested by the citrus leaf miner.

Method of recording of observation of population dynamics of citrus leaf miner in nursery: Population dynamic of *Phyllocnistis citrella* on citrus in nursery stage was conducted where no chemical treatments were taken throughout the research period. Fifty seedlings were kept 5 m × 5 m area in open environment. From that, randomly ten seedlings were selected for population studies. Total leaves and infested leaves counted on ten randomly selected seedlings from each treatment were done. The observation was taken at eight days interval.

Method of correlation of weather parameters

Correlation of weather parameters in abundance of citrus leaf miner was studied for the environmental factors mainly maximum and minimum temperature, average rainfall, evaporation as well as percent of relative humidity (RH %). Simple correlation between population of citrus leaf miner and weather parameters will be calculated. The data were subjected to statistical analysis for calculation of "r" values. The "r" values, so worked out, were compared with table values for interpretation of the correlations.

Calculation of percent leaves infestation

The data on percent infestation of leaf miner on citrus was calculated by adopting the following formula.

$$\text{Percent Leaves Infestation} = \frac{\text{Infested Leaves}}{\text{Total Leaves}} \times 100$$

Statistical analysis: The data generated in respect of percent leaf infestation due to leaf miner on citrus was transformed into square root value when value in between 0-30% as per Gomez and Gomez, (1984) and then subjected to statistical analysis to test the level of significance of treatment.

Results and Discussions

Observations were recorded on leaf infestation of citrus leaf miner at one day before spraying, seven and fourteen days after sprayings of each application. Total three sprayings were executed from September to November 2019. The infestation on leaves was recorded and from which percent leaves infestation of leaf miner was worked out.

In connection with above data obtaining during course of investigation, were transformed appropriately and subjected to the statistical analysis by standard procedure. The analyzed data on above aspect of each application and discussed as under.

Population dynamics of citrus leaf miner

Incidence of citrus leaf miner on Nagpur mandarin seedlings was initiated from 36th meteorological week (MW) at 14.96 percent leaves infestation and it was reached peak at 70.25 percent and it decline afterword. The percent leaves infestation of citrus leaf miner on Nagpur mandarin was in the range of 14.96 to 70.25 percent during 36th to 46th MW in year 2019-20 (table 2).

These findings are similar in Charles *et al.* (2007) studied on the seasonal abundance of citrus leaf miner, *Phyllocnistis citrella* (Stainton) (Lepidoptera: Gracillariidae), in a Florida citrus grove for 5 years by scouting weekly. Leaf miner populations were highest during the warmer months (April to September) and lowest during the cooler months (November to March) and populations peaked during June.

Also, Lad *et al.* (2010b) [23] studied on seasonal incidence of *Phyllocnistis citrella* (stainton) on trees of Nagpur mandarin and revealed that two peaks of the incidence were recorded during the year (second week of October 2005 and fifth week of March 2006. The larval incidence was minimum during fourth week of April 2005 (1.50%), and maximum during fifth week of March 2006 (19.46%) with peaks during second week of October 2005 (19.00%) and fifth week of March 2006 (19.46%). This is in line with the present findings.

Table 2: Population dynamics of citrus leaf miner

SMW	Period	Leaves infestation %	Temp. (°C)		R. H. (%)		Rainfall(mm)	Evaporation
			Max	Min	Mor	Eve		
(Sep)36th	06 Sep - 09 Sep	14.96	28.8	23.8	91	84	188	1.6
(Sep)37th	10 Sep - 16 Sep	34.65	30.3	24.1	86	62	40	2.8
(Sep)38th	17 Sep - 23 Sep	43.52	29.3	24.3	90	75	106	2.8
(Sep)39th	24 Sep - 30 Sep	50.94	29.7	23.8	94	80	93	2.1
(Oct)40th	01 Oct - 07 Oct	53.82	31.1	23.2	81	58	9	3.6
(Oct)41st	08 Oct - 14 Oct	60.48	31.9	22.9	71	52	0	4.4
(Oct)42nd	15 Oct - 21 Oct	70.25	30.8	21.1	81	58	53	4.4
(Oct)43rd	22 Oct - 28 Oct	54.64	27.8	20.3	88	77	48	3.7
(Oct)44th	29 Oct - 04 Nov	40.33	31.5	21.8	76	52	0	3.5
(Nov)45th	05 Nov - 11Nov	43.56	31.3	20.9	78	50	0	4.4
(Nov)46th	12 Nov - 18 Nov	45.33	30.6	17.6	74	47	0	3.1

Correlation of citrus leaf miner infestation with weather parameter: Incidence of citrus leaf miner on nursery plant of Nagpur mandarin, revealed in significant and positive correlated with evaporation (r = 0.560) and non-significant and positive correlated with maximum temperature (r = 0.312), whereas correlation was negatively non -significant with minimum temperature (r = −0.285). Similarly, morning and evening relative humidity negatively correlate and non-significant (r = −0.347) and (r = −0.352) and rainfall was also non-significant and negatively correlated (r = −0.536) was noticed in citrus leaf miner infestation (table 3).

Table 3: Correlation coefficient factor for leaf miner on citrus crop and abiotic factors

Pest	MaxT (X_1)	MinT (X_2)	RHm (X_3)	RHe (X_4)	RF (X_5)	Evaptn (X_6)
Citrus leaf miner	0.312	-0.285	-0.347	-0.352	-0.536	0.560**

Coefficient of determination (R^2) = 0.733 and
** Level of significance: P = 0.01 and P = 0.05

Effect of different on insecticides against citrus leaf miner in citrus nursery.

Percent infestation of citrus leaf miner after first application

A. Percent infestation of citrus leaf miner at 7 DAS of first application.

From the data presented in table 4, observed that, all the modules were superior over the control (water spray) in recording of lowest percent of infestation of leaf miner. The Module 7 (Azadirachtin 1500 ppm 3.0 ml/lit. fb Diflubenzuron 25 WP 3.2 gm/lit. fb Profenofos (40%) +Cypermethrin (4%) EC @ 2.0 ml/lit.) recorded 17.27 percent leaf miner infestation found statistically significant and was at par with Module 2 and followed by Module 6 which recorded 18.23 percent leaves infestation. Followed by Module 3 and was at par with Module 1.

Remaining modules Module 4 and Module 5 recorded 22.25 and 23.40 percent leaves infestation. The maximum percent leaves infestation was recorded in control (water spray) i.e. 24.34 percent leaves infestation.

B. Percent infestation of citrus leaf miner at 14 DAS of first application.

From the data presented in table 4, observed that, all the modules were superior over the control (water spray) in recording of lowest percent of infestation of leaf miner. The Module 2 (Azadirachtin 1500 ppm 3.0 ml/lit. fb Thiamethoxam 25 WP @ 2.5 gm/lit fb Thiamethoxam (12.6%) +Lambdacyhalothrin (9.5%) ZC @ 0.5 ml/lit.) recorded lowest percent leaves infestation i.e. 16.25 percent and was at par with Module 7 which recorded 16.44 percent leaves infestation.

The next effective group of modules was Module 6, Module 1, Module 3, Module 4 and Module 5 which recorded 17.27, 19.79, 20.28, 22.03 and 22.38 percent leaves infestation

respectively. Module 1 and Module 3 was at par with each other and Module 4 and Module 5 was par with each other. The maximum percent leaves infestation was recorded in control (water spray) i.e. 26.44 percent leaves infestation.

Table 4: Effect of different insecticides on percent infestation of citrus leaf miner after first application

Mo. No	Module detail	% leaves infestation at	
		7DAS	14DAS
1	Azadirachtin 1500 ppm @ 3.0 ml/lit. fb Thiamethoxam 25 WP @ 2.5 gm/lit fb Chloratraniliprole (10%) + Lambdacyhalothrin (5%) ZC @ 1.5 ml/lit.	20.68 (4.54)	19.79 (4.44)
2	Azadirachtin 1500 ppm @ 3.0 ml/lit. fb Thiamethoxam 25 WP @ 2.5 gm/lit fb Thiamethoxam (12.6%) + Lambdacyhalothrin (9.5%) ZC @ 0.5 ml/lit.	17.31 (4.16)	16.25 (4.03)
3	Azadirachtin 1500 ppm @ 3.0 ml/lit. fb Thiamethoxam 25 WP @ 2.5 gm/lit fb Profenofos (40%) + Cypermethrin (4%) EC @ 2.0 ml/lit.	20.60 (4.53)	20.28 (4.50)
4	Azadirachtin 1500 ppm @ 3.0 ml/lit. fb Imidacloprid 17.8 SL @ 1.06 ml/lit. fb Chloratraniliprole (10%) + Lambdacyhalothrin (5%) ZC @ 1.5 ml/lit.	22.25 (4.71)	22.03 (4.69)
5	Azadirachtin 1500 ppm @ 3.0 ml/lit. fb Imidacloprid 17.8 SL @ 1.06 ml/lit. fb Profenofos (40%) + Cypermethrin (4%) EC @ 2.0 ml/lit.	23.40 (4.83)	22.38 (4.73)
6	Azadirachtin 1500 ppm @ 3.0 ml/lit. fb Diflubenzuron 25 WP @ 3.2 gm/lit. fb Thiamethoxam (12.6%) + Lambdacyhalothrin (9.5%) ZC @ 0.5 ml/lit.	18.23 (4.26)	17.27 (4.15)
7	Azadirachtin 1500 ppm @ 3.0 ml/lit. fb Diflubenzuron 25 WP @ 3.2 gm/lit. fb Profenofos (40%) + Cypermethrin (4%) EC @ 2.0 ml/lit.	17.27 (4.15)	16.44 (4.05)
8	Control (water spray).	24.34 (4.93)	26.44 (5.14)
F test		SIG	SIG
SE (m) ±		0.76	0.66
CD @ 5%		2.30	2.01

(Figures in parentheses are corresponding values of square root transformation.)

Percent infestation of citrus leaf miner after second application

A. Percent infestation of citrus leaf miner at 7 DAS of second application

From the data presented in table 5, observed that, all the modules were significantly superior over the control (water spray). Minimum percent leaves infestation in Module 2 (Azadirachtin 1500 ppm @ 3.0 ml/lit. fb Thiamethoxam 25 WP @ 2.5 gm/lit fb Thiamethoxam (12.6%) +Lambdacyhalothrin (9.5%) ZC @ 0.5 ml/lit.) was most significant over all the modules which recorded lowest percent leaves infestation i.e. 14.74 percent followed by Module 7 (15.39%).

The next effective module was Module 6 which recorded 16.67 percent leaves infestation followed by Module 1 (18.47%) and was at par with Module 3 (19.91%). Remaining modules i.e. Module 4 and Module 5 showed 20.09 and 22.55 percent leaves infestation respectively. The maximum percent leaves infestation was observed in control (water spray) i.e. 26.65 percent leaves infestation.

Table 5: Effect of different insecticides on percent infestation of citrus leaf miner after second application

Mo. No	Module detail.	Percent leaves infestation at	
		7DAS	14DAS
1	Azadirachtin 1500 ppm @ 3.0 ml/lit. fb Thiamethoxam 25 WP @ 2.5 gm/lit fb Chloratraniliprole (10%) + Lambdacyhalothrin (5%) ZC @ 1.5 ml/lit.	18.47 (4.29)	15.55 (3.94)
2	Azadirachtin 1500 ppm @ 3.0 ml/lit. fb Thiamethoxam 25 WP @ 2.5 gm/lit fb Thiamethoxam (12.6%) +Lambdacyhalothrin (9.5%) ZC @ 0.5 ml/lit.	14.74 (3.83)	12.54 (3.54)
3	Azadirachtin 1500 ppm @ 3.0 ml/lit. fb Thiamethoxam 25 WP @ 2.5 gm/lit fb Profenofos (40%) + Cypermethrin (4%) EC @ 2.0 ml/lit.	19.01 (4.36)	16.26 (4.03)
4	Azadirachtin 1500 ppm @ 3.0 ml/lit. fb Imidacloprid 17.8 SL 1.06 ml/lit. fb Chloratraniliprole (10%) + Lambdacyhalothrin (5%) ZC @ 1.5 ml/lit.	20.09 (4.48)	15.33 (3.91)
5	Azadirachtin 1500 ppm @ 3.0 ml/lit. fb Imidacloprid 17.8 SL 1.06 ml/lit. fb Profenofos (40%) + Cypermethrin (4%) EC @ 2.0 ml/lit.	22.55 (4.75)	20.46 (4.52)
6	Azadirachtin 1500 ppm @ 3.0 ml/lit. fb Diflubenzuron 25 WP 3.2 gm/lit. fb Thiamethoxam (12.6%) +Lambdacyhalothrin (9.5%) ZC @ 0.5 ml/lit.	16.67 (4.08)	16.05 (4.01)
7	Azadirachtin 1500 ppm @ 3.0 ml/lit. fb Diflubenzuron 25 WP 3.2 gm/lit. fb Profenofos (40%) + Cypermethrin (4%) EC @ 2.0 ml/lit.	15.39 (3.92)	15.18 (3.99)
8	Control (water spray).	26.65 (5.16)	28.23 (5.31)
F test		Sig	Sig
SE (m) ±		0.63	0.60
CD @ 5%		1.91	1.82

(Figures in parentheses are corresponding values of square root transformation.)

B. Percent infestation of citrus leaf miner at 14 DAS of second application

Data presented in table 5 indicated that all the modules were significantly superior over control (water spray) in recording of minimum percent leaves infestation of CLF at 14 DAS after second application. Module 2 (Azadirachtin 1500 ppm @ 3.0 ml/lit. fb Thiamethoxam 25 WP @ 2.5 gm/lit fb Thiamethoxam (12.6%) +Lambdacyhalothrin (9.5%) ZC @ 0.5 ml/lit.) was significantly superior all the modules and recorded lowest (12.54%).

The next effective modules were Module 7 and Module 4 found at par with each other and recorded 15.18 and 15.33

percent leaves infestation respectively and was followed by Module 1 which recorded 15.55 percent leaves infestation. From the remaining modules i.e. Module 6 and Module 3 was at par with each other and recorded 16.05 and 16.26 percent leaves infestation respectively and followed by Module 5 (20.46%). The maximum infestation of leaf miner was observed in control (water spray) i.e. 28.23 percent leaves infestation.

Percent infestation of citrus leaf miner after third application

A. Percent infestation of citrus leaf miner at 7 DAS of third application.

From the data presented in table 6, that all modules were significantly superior over the control (water spray). The lowest (8.3%) leaves infestation was recorded in Module 4 (Azadirachtin 1500 ppm 3.0 ml/lit. fb Imidacloprid 17.8 SL 1.06 ml/lit. fb Chloratraniliprole (10%) + Lamdacyhalothrin (5%) ZC @ 1.5 ml/lit.) and it was at par with Module 1 which recorded 9.14 percent leaves infestation.

Next effective group of modules was Module 2 and Module 7 and was at par with each other which recorded 12.30 and 12.90 percent leaves infestation respectively. Remaining module *viz.*, Module 5, module 3 and module 6 recorded 13.12, 13.34 and 14.84 percent leaves infestation respectively and was at par with each other. The maximum i.e. 28.90 percent leaves infestation of leaf miner was observed in control (water spray).

B. Percent infestation of citrus leaf miner at 14 DAS of third application.

From the data presented in table 6, that all the modules were significantly superior over the control. The lowest percent leaves infestation was recorded in Module 4 (Azadirachtin 1500 ppm @ 3.0 ml/lit. fb Imidacloprid 17.8 SL @ 1.06 ml/lit. fb Chloratraniliprole (10%) + Lambdacyhalothrin (5%) ZC @ 1.5 ml/lit.) i.e. 5.61 percent and followed by Module 2 (7.24%) and Module 7 (7.89%) and Module 1 and Module 7 at par with each other.

The next effective module was Module 2 and Module 5 recorded 9.24, 9.45 percent leaves infestation respectively and was at par with each other. The remaining modules i.e. Module 6 and module 3 showed 10.7 and 10.81 percent leaves infestation respectively and was at par with each other. The maximum percent leaves infestation was observed in control (water spray) i.e.30.00 percent.

Table 6: Effect of different insecticides on percent infestation of citrus leaf miner after third application

Mo. No	Module detail.	% leaves infestation at	
		7DAS	14DAS
1	Azadirachtin 1500 ppm @ 3.0 ml/lit. fb Thiamethoxam 25 WP @ 2.5 gm/lit fb Chloratraniliprole (10%) + Lambdacyhalothrin (5%) ZC @ 1.5 ml/lit.	9.14 (3.02)	7.24 (2.69)
2	Azadirachtin 1500 ppm @ 3.0 ml/lit. fb Thiamethoxam 25 WP @ 2.5 gm/lit fb Thiamethoxam (12.6%) +Lambdacyhalothrin (9.5%) ZC @ 0.5 ml/lit.	12.30 (3.50)	9.24 (3.04)
3	Azadirachtin 1500 ppm @ 3.0 ml/lit. fb Thiamethoxam 25 WP @ 2.5 gm/lit fb Profenofos (40%) + Cypermethrin (4%) EC @ 2.0 ml/lit.	13.34 (3.65)	10.81 (3.28)
4	Azadirachtin 1500 ppm @ 3.0 ml/lit. fb Imidacloprid 17.8 SL 1.06 ml/lit. fb Chloratraniliprole (10%) + Lambdacyhalothrin (5%) ZC @ 1.5 ml/lit.	8.3 (2.88)	5.61 (2.36)
5	Azadirachtin 1500 ppm @ 3.0 ml/lit. fb Imidacloprid 17.8 SL 1.06 ml/lit. fb Profenofos (40%) +Cypermethrin (4%) EC @ 2.0 ml/lit.	13.12 (3.62)	9.45 (3.07)
6	Azadirachtin 1500 ppm @ 3.0 ml/lit. fb Diflubenzuron 25 WP 3.2 gm/lit. fb Thiamethoxam (12.6%) +Lambdacyhalothrin (9.5%) ZC @ 0.5 ml/lit.	14.82 (3.84)	10.7 (3.27)
7	Azadirachtin 1500 ppm @ 3.0 ml/lit. fb Diflubenzuron 25 WP 3.2 gm/lit. fb Profenofos (40%) + Cypermethrin (4%) EC @ 2.0 ml/lit.	12.9 (3.59)	7.89 (2.80)
8	Control (water spray).	28.90 (5.37)	30.00 (5.47)
F test		Sig	Sig
SE (m) ±		0.32	0.41
CD @ 5%		0.98	1.24

(Figures in parentheses are corresponding values of square root transformation.)

Cumulative effect of three applications on percent infestation of citrus leaf miner

A. Cumulative percent infestation of citrus leaf miner at 7 DAS: The result showed in table 7 indicated that all the modules were recorded minimum percent leaves infestation of CLF in nursery and found significantly superior over the control (water spray). From the cumulative data of 7th days after spraying all three applications revealed that, Module 2 (Azadirachtin 1500 ppm @ 3.0 ml/lit. fb Thiamethoxam 25 WP @ 2.5 gm/lit fb Thiamethoxam (12.6%) +Lambdacyhalothrin (9.5%) ZC @ 0.5 ml/lit.) was significantly superior over restbof the modules and recorded lowest percent leaves infestation of leaf miner i.e. 14.78 and was at par with Module7 which recorded (15.18%).

Next effective modules were Module 1, Module 6 and Module 4 which recorded 16.10, 16.57 and 16.88 percent leaves infestation respectively and was at par with each other. Remaining modules i.e. Module 3 and Module 5 recorded 15.78 and 17.43 percent leaves infestation respectively. The control (water spray) treatment was recorded maximum percent i.e. 28.23.

B. Cumulative percent infestation of citrus leaf miner at 14 DAS

The result showed in table 7 indicated that all the modules were significantly superior over the control (water spray) by recording of minimum percent leaves infestation of CLF in nursery. From the cumulative data of 14th days after spraying all three applications revealed that, Module 2 (Azadirachtin 1500 ppm @ 3.0 ml/lit. fb Thiamethoxam 25 WP @ 2.5 gm/lit fb Thiamethoxam (12.6%) +Lambdacyhalothrin (9.5%) ZC @ 0.5 ml/lit.) was significantly superior was over other modules recorded lowest percent leaves infestation of leaf miner i.e. 12.68 and was at par with Module 7 (13.17%).

Next effective group of modules were Module 1, Module 4 and Module 6 which recorded 14.19, 14.32 and 14.67 percent leaves respectively and was at par with each other. Remaining modules i.e. Module 3 and Module 5 recorded 17.65 and

19.69 percent leaves infestation. The maximum i.e. 26.63 percent leaves infestation was recorded in control (water spray).

Table 7: Cumulative effect of three applications on percent infestation of citrus leaf miner

Mo. No	Module Detail	% leaves infestation at	
		7DAS	14DAS
1	Azadirachtin 1500 ppm @ 3.0 ml/lit. fb Thiamethoxam 25 WP @ 2.5 gm/lit fb Chloratraniliprole (10%) + Lambdacyhalothrin (5%) ZC @ 1.5 ml/lit.	16.10 (4.01)	14.19 (3.76)
2	Azadirachtin 1500 ppm @ 3.0 ml/lit. fb Thiamethoxam 25 WP @ 2.5 gm/lit fb Thiamethoxam (12.6%) +Lambdacyhalothrin (9.5%) ZC @ 0.5 ml/lit.	14.78 (3.84)	12.68 (3.56)
3	Azadirachtin 1500 ppm @ 3.0 ml/lit. fb Thiamethoxam 25 WP @ 2.5 gm/lit fb Profenofos (40%) + Cypermethrin (4%) EC @ 2.0 ml/lit.	17.65 (4.20)	15.78 (3.97)
4	Azadirachtin 1500 ppm @ 3.0 ml/lit. fb Imidacloprid 17.8 SL @ 1.06 ml/lit. fb Chloratraniliprole (10%) + Lambdacyhalothrin (5%) ZC @ 1.5 ml/lit.	16.88 (4.10)	14.32 (3.78)
5	Azadirachtin 1500 ppm @ 3.0 ml/lit. fb Imidacloprid 17.8 SL 1.06 ml/lit. fb Profenofos (40%) + Cypermethrin (4%) EC @ 2.0 ml/lit.	19.69 (4.43)	17.43 (4.17)
6	Azadirachtin 1500 ppm @ 3.0 ml/lit. fb Diflubenzuron 25 WP @3.2 gm/lit. fb Thiamethoxam (12.6%) +Lambdacyhalothrin (9.5%) ZC @ 0.5 ml/lit.	16.57 (4.07)	14.67 (3.83)
7	Azadirachtin 1500 ppm @ 3.0 ml/lit. fb Diflubenzuron 25 WP @ 3.2 gm/lit. fb Profenofos (40%) +Cypermethrin (4%) EC @ 2.0 ml/lit.	15.18 (3.89)	13.17 (3.62)
8	Control (water spray).	26.63 (5.16)	28.23 (5.31)
F test		Sig	Sig
SE (m) ±		0.57	0.56
CD @ 5%		1.73	1.69

(Figures in parentheses are corresponding values of square root transformation.)

Table 8: Overall cumulative effect of three sprayings on percent infestation of citrus leaf miner on Nagpur mandarin

Mo. No	Module detail	% Leaves Infestation
1	Azadirachtin 1500 ppm @ 3.0 ml/lit. fb Thiamethoxam 25 WP @ 2.5 gm/lit fb Chloratraniliprole (10%) + Lambdacyhalothrin (5%) ZC @ 1.5 ml/lit.	15.15 (3.89)
2	Azadirachtin 1500 ppm @ 3.0 ml/lit. fb Thiamethoxam 25 WP @ 2.5 gm/lit fb Thiamethoxam (12.6%) +Lambdacyhalothrin (9.5%) ZC @ 0.5 ml/lit.	13.73 (3.70)
3	Azadirachtin 1500 ppm @ 3.0 ml/lit. fb Thiamethoxam 25 WP @ 2.5 gm/lit fb Profenofos (40%) + Cypermethrin (4%) EC @ 2.0 ml/lit.	16.71 (4.08)
4	Azadirachtin 1500 ppm @ 3.0 ml/lit. fb Imidacloprid 17.8 SL @ 1.06 ml/lit. fb Chloratraniliprole (10%) + Lambdacyhalothrin (5%) ZC @ 1.5 ml/lit.	15.60 (3.95)
5	Azadirachtin 1500 ppm @ 3.0 ml/lit. fb Imidacloprid 17.8 SL @ 1.06 ml/lit. fb Profenofos (40%) + Cypermethrin (4%) EC @ 2.0 ml/lit.	18.56 (40)
6	Azadirachtin 1500 ppm @ 3.0 ml/lit. fb Diflubenzuron 25 WP @ 3.2 gm/lit. fb Thiamethoxam (12.6%) +Lambdacyhalothrin (9.5%) ZC @ 0.5 ml/lit.	15.62 (3.95)
7	Azadirachtin 1500 ppm @ 3.0 ml/lit. fb Diflubenzuron 25 WP @ 3.2 gm/lit. fb Profenofos (40%) + Cypermethrin (4%) EC @ 2.0 ml/lit.	14.18 (3.76)
8	Control (water spray).	27.43 (5.23)
	'F' test	Sig
	SE(m) ±	0.56
	CD@5%	1.71

(Figures in parentheses are corresponding values of square root transformation.)

Overall Cumulative effect of three applications on percent infestation of citrus leaf miner

The data presented in table 9 indicated that all the modules were significantly superior over control. Lowest i.e. 13.73 percent leaves infestation was observed in Module 2 (Azadirachtin 1500 ppm @ 3.0 ml/lit. fb Thiamethoxam 25 WP @ 2.5 gm/lit fb Thiamethoxam (12.6%) +Lambdacyhalothrin (9.5%) ZC @ 0.5 ml/lit.) and found significantly superior over control and followed by Module 7 which was recorded 14.18 percent leaves infestation.

The next effective modules were Module 1, Module 4 and Module 6 which recorded 15.15, 15.60 and 15.62 percent leaves infestation.

Remaining module i.e. Module 5 recorded 18.56 percent leaves infestation. Whereas, the maximum leaves infestation was recorded in control (water spray) i.e. 27.43 percent leaves infestation.

The efficacy of Module 2 (Azadirachtin 1500 ppm fb Thiamethoxam 25 WP fb Allika^{R} (Thiamethoxam (12.6%) +Lambdacyhalothrin (9.5%) ZC) was most significant in reducing infestation of citrus leaf miner.

Similar findings are also reported by Chavan (2014) who reported that the percent leaf infestation citrus leaf miner, *Phyllocnistis citrilla* (Stainton) in citrus nursery was recorded in the treatment Thiamethoxam and found significantly superior over all the treatments.

Shinde *et al.* (2015) also reported amongst the different new molecule of insecticides tested, Thiamethoxam 25 WG (0.06%) was significantly superior over all treatments recorded cumulative lowest (4.50%) (leaf miner *Phyllocnistis citrella* Stainton) infestation in nursery.

Conclusion

The incidence of citrus leaf miner on Nagpur mandarin seedlings began in the 36th meteorological week, reaching a

peak of 70.25% infestation in the 42nd week before declining. Leaf miner infestation was higher in newly sprouted leaves, showing significant positive correlation with evaporation and non-significant positive correlation with high temperature, and negative correlation with low temperature, morning relative humidity, evening relative humidity, and rainfall. All insecticide modules, when applied in their recommended doses, proved effective against citrus leaf miner. Throughout the experiment, all module treatments exhibited a similar trend of reducing leaf miner infestation at both 7 and 14 days after each application. To maintain low levels of citrus leaf miner infestation, a minimum of three sprayings of insecticides was necessary. Module 2, consisting of Azadirachtin 1500 ppm, Thiamethoxam 25 WP, and Thiamethoxam (12.6%) + Lambdacyhalothrin (9.5%) ZC, was found to be significantly effective against citrus leaf miner. The next most effective module was Module 7 (Azadirachtin 1500 ppm, Diflubenzuron 25 WP, and Profenofos (40%) + Cypermethrin (4%) EC), followed by Modules 1, 4, 6, 3, and 5. The selection of insecticide molecules for pest management should consider factors such as formulation, crop stage, toxicity to natural enemies, persistency, and residual toxicity, necessitating further research in this area.

Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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