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Efficacy of Chemical Insecticides against Citrus Leaf Miner (*Phyllocnistis citrella* Stainton) in South-western Bangladesh

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Abstract

The citrus leaf miner (CLM) is a major threat to citrus production in the World including Bangladesh. Insecticides are a commonly utilized and effective method to manage this pest in field conditions. However, judicious application of insecticides is crucial for successful and cost-effective management of CLM. Therefore, the present study aimed to evaluate the efficacy of insecticides namely imidacloprid, cypermethrin, chlorpyrifos and abamectin, respectively, against CLM in field conditions, maintaining a randomized complete block design with three replicates. All the treatments applied in experiment had preventive action against the CLM compared with the untreated control. Results revealed that among the treatments, the imidacloprid statistically provided the lowest leaf infestation after 1st Spray (6.66% and 4.27%), 2nd Spray (5.76% and 2.50%), 3rd Spray (0.84% and 0.11%) relative to control. Among insecticides applied, imidacloprid treated plots demonstrated the most significant reduction in larval counts all through the sprays. However, for natural enemies (ladybird beetle, *Coccinella septempunctata*) count, statistically maximum number of NEs was observed in untreated control plots relative to treated plots. Based on the findings, it could be inferred that imidacloprid was proved most effective in controlling CLM compared to other applied insecticides.

Keywords: Chemical insecticide, Citrus leaf miner, Field management, Imidacloprid, Natural enemies

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Introduction

Citrus (*Citrus aurantium var*. sinensis) is a highly nutritious and economically important fruit belonging to the family Rutaceae. According to FAO statistics, the global citrus production in 2021 was approximately 161.8 million tons, ranking third among all the fruit crops where the lead producing countries over globe are Brazil, U.S.A, India, China, Mexico, and Spain (FAOSTAT, 2023; Etebu and Nwauzoma, 2014). Despite the fact that it has high economic, medicinal and nutritive value, it does not yet gain so much popularity in Bangladesh. However, production of citrus boosted significantly, rising from 18,712 tons in 1972 to 164,008 tons in 2021 in Bangladesh (Knoema, 2021). Citrus consumption in Bangladesh had noticeably augmented during and after the pandemic of COVID-19 (Shakil, 2021). Nowadays, it has gained popularity and is simultaneously being cultivated in different parts of our country. Initially the regions of Bangladesh where citrus is widely cultivated are Chittagong hill tracts, Sylhet, Gaibandha, Jessore, Khagrachari, Panchagarh etc. (Majumder, 2009). Considering the nutritive value and taste of the fruit, farmers of various locales in Bangladesh are being motivated and encouraged to cultivate these crops more and more.

However, the production of this fruit is greatly hampered by a variety of insect pests around the citrus growing region of the globe including Bangladesh (Rahman et al., 2005). Among the various insect pests, citrus leaf miner (Lepidoptera: Gracillariidae) is one of the devastating insect pests of citrus (Chhetry et al., 2011; Olabiyi, et al., 2022; Nawaz et al., 2021)). It was initially described from Calcutta, India, in 1856 (Stainton, 1856; Mustafa, et al., 2014), and then extensively scattered in citrus-producing regions part in Asia, Australia, East Africa, China and Bangladesh (Raza, et al., 2017). Adult of CLM are tiny, silvery in color with a wingspan ranging to 4 mm (Tzanakakis and Katsoyannos, 2021). However, larvae produce serpentine mines on the leaf portion that can affect photosynthesis of the plant (Raimondo et al., 2013). It can rapidly stunt the growth of young citrus plants in comparison with fully mature plants (Arshad et al., 2018).

To manage the pest, many control measures have been described and used over years, namely biological, cultural, physical, chemical control etc. of which chemical control is still the principal means in most cropping systems for the citrus growers to control citrus leaf miner (Hasan et al., 2021). Because these are relatively cheap and easy to apply, fast-acting and controlled effectively in most instances however it is a matter of great grief that farmers are not aware of dosage and frequency of insecticide application, even whether these chemicals are non-persistent or persistent which have great adverse effects on the environment. Thus, application of higher dosage and frequency of broad-spectrum persistent insecticides by the untrained and unconscious farmers make the whole environment in threat. Not only that but also it increases farmers' expenditure, develops insect resistance as well as kills different beneficial insects (Mafi and Ohbayashi, 2006).

So, to avoid these serious hazards and to prevent insecticide resistance, entomologists always emphasize the application of non-persistent and biodegradable insecticides at recommended dose and interval. It is very apparent that there is no alternative to intelligent sections of insecticides as well as their dosage and frequency of application. But research works in this top concerning issue is poor and sketchy. Therefore, the study was undertaken to assess the effectiveness of selected chemical insecticide against CLM in field conditions.

Materials and Methods

Experimental Site and Setup

The research experiment was performed at Agrotechnology Discipline field laboratory (22°47′57.84″N 89°31′53.48″E), Khulna University, Khulna, Bangladesh belonging to "AEZ-13" from January 2015 to September 2015. The experimental field experiences moderately high temperatures and significant rainfall during *kharif* period, while the *rabi* season is considered with lower temperature and limited rainfall. 15 sweet orange (*Citrus aurantium var*. sinensis) plants were selected for this experiment. Row to row and plant to plant spacing of 5 m × 5 m was maintained in the orchard. The experiment was laid with RCBD design maintaining three replications. One plant was considered as one replication. For their better growth and development, all necessary intercultural operations were optimally done on due time. The weekly observations were made to check for incidence of pests after treatment application.

The treatments applied were namely $T_{0=}$ control (only water), T_1= Imidacloprid with 2.5 ml/ 10L, T_2= Cypermethrin with1 ml/L, T_3= Chlorpyrifos with 7 ml/L, T_4= Abamectin 1.2 ml/L. To evade drifting of insecticides to neighboring citrus plants special care was maintained during application time. Treatments were imposed when pests reached sufficient incidence levels on plants. Three sprays were done with the help of knapsack sprayer at fortnightly intervals. In the control field an equal volume of water was applied as treatment.

Data collection and calculation

Estimation of infested leaf percentage

Number of infested and Number of total leaves per plant was counted visually and then its calculated in percentage using following formulae

Percentages of infested leaf $=\frac{Number\ of\ infested\ leaves\ (IL)}{Number\ of\ total\ leaves\ \ (TL)} \times 100$

The observations were recorded one day before and 1 week and 2 weeks after imposition of treatments.

Number of larvae (miner) per plant

The number of larvae per infested leaves of plant was visually counted using magnifying glass one day before and 1 week and 2 weeks after imposition of treatments.

The Number of natural enemies per plant

The orientation of natural enemies (ladybird beetle, *Coccinella septempunctata*) was visually observed from each citrus plant. The observations were recorded one day before and 1 week and 2 weeks after the implications of management tactics (insecticide applications).

Analysis of data

The recorded data were subjected for one-way ANOVA with the Statistix-10 program where the mean differences were separated by Duncan's New Multiple Range Test (DMRT).

Results and Discussion

Effect of Synthetic Insecticides on the Percentage of Infested Leaf

The data presented in Figure 1 demonstrate the differential efficacy of various insecticides in reducing leaf infestation over time, compared to an untreated control (T_0). After an initial increase in infestation at the first spray (possibly due to a delay in insecticide action), it showed a consistent decrease in leaf infestation, reaching a remarkable low of 0.11% by the end of the study period. This suggests Imidacloprid has both immediate and sustained efficacy against the CLM. Patil (2013) found that two sprays of Imidacloprid at 0.005% concentration at 15-day intervals after the initiation of new flushes were highly effective in reducing CLM infestation (14.9% to 18.8%) and resulted in higher fruit yields.

Cypermethrin (T_2), Chlorpyrifos (T_3), and Abamectin (T_4) also demonstrated pest control capabilities, though less different than Imidacloprid. These treatments showed similar patterns of efficacy, with gradual reductions in leaf infestation over time. By the study's conclusion, they achieved infestation rates of 0.59%, 1%, and 0.76% respectively, which is higher than Imidacloprid. The untreated control (T_0) exhibited a steady increase in leaf infestation throughout the study, climbing from 9.79% to 18.55%. Shinde et al. (2017) evaluated the efficiency of insecticides on CLM and found Imidacloprid 17.8 SL at 0.06% showed a significant reduction in leaf miner infestation, recording 8.52% infested leaves, which was among the lowest compared to other treatments. The environmental conditions (significant rainfall and moderately high temperatures) during the study, created optimal conditions for CLM proliferation and new leaf growth. The continuous increase in leaf infestation in the untreated control plot from 9.79% to 18.55% highlights the impact of favorable environmental conditions on CLM populations when no control measures are applied.

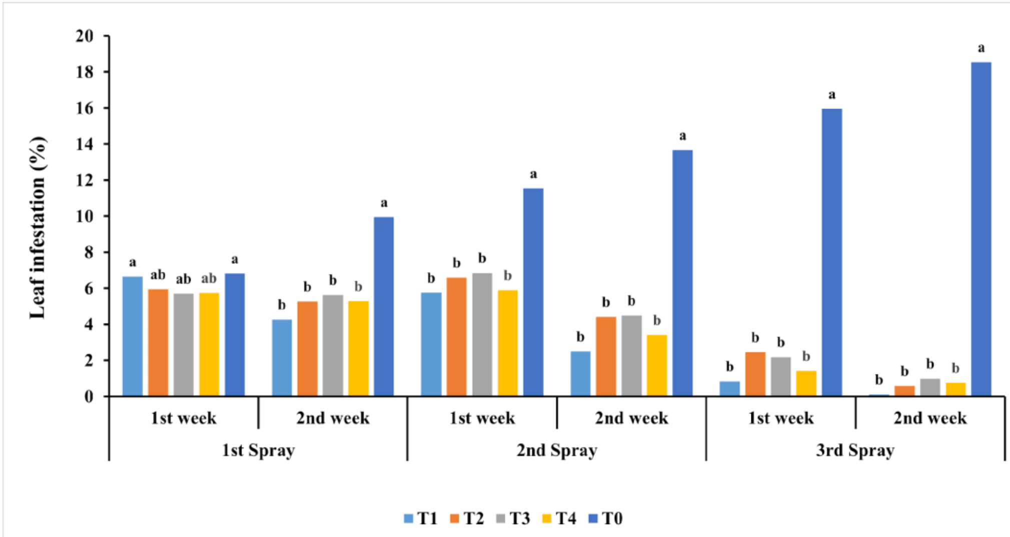

Fig. 1. Effect of four synthetic insecticides on leaf infestation caused by CLM on citrus plant. Means followed by similar letter(s) are not significantly different. [Where, T_1=Imidacloprid, T_2=Cypermethrin, T_3= Chlorpyrifos, T_4= Abamectin and T_0=Control]

Effect of Synthetic Insecticides on Number of Larvae

The Data displays the number of larvae over a series of treatments using four different synthetic insecticides (T_1, T_2, T_3, T_4) and an untreated control (T_0) (Table 1). The data spans from before treatment to after three spray applications at different time intervals. Before treatment, the initial larvae count was different across treatments, with T_1 starting at 4.88, T_2 at 4.88, T_3 at 4.11, T_4 at 4.55, and the control (T_0) at 4.77. After the first spray application, there was a decrease in larvae count for all treatments. For example, T_1 decreased from 3.88 to 2.11, T_2 from 4.88 to 2.44, T_3 from 4.11 to 2.00, T_4 from 3.55 to 1.88, while T_0 (control) increased to 9.44. The second and third spray applications showed a significant reduction in larvae count across all treatments. T_1 (Imidacloprid) demonstrated the most significant and consistent reduction in larvae count, achieving near-complete control by the end of the third spray. Imidacloprid is a neonicotinoid with strong systemic properties. Once applied as foliar spray, it is absorbed and translocated throughout the citrus plant. This allows it to target larvae feeding inside leaf tissues, where contact insecticides are less effective. T_2, T_3, and T_4 also showed significant reductions but were less effective compared to T_1. By the end of the third spray, T_2 reduced to 0.88, T_3 to 0.88, and T_4 to 0.77. T_0 (Control) showed a continuous increase in larvae count (12.56). The rise in larvae count in the untreated control (T_0) from 4.77 to 12.56 suggests that moderately high temperatures and significant rainfall during the kharif period is favourable for CLM larvae proliferation.

Table 1. Effect of four synthetic insecticides on the number of larvae plant^{-1}

Treatment	No. of larvae plant^{-1}						
	Before Treatment	1st Spray		2nd Spray		3rd Spray	
		1st week	2nd week	1st week	2nd week	1st week	2nd week
T_1	4.88	2.11b	0.55b	4.33b	1.77b	0.11b	0.33b
T_2	4.88	2.44b	1.00b	5.44b	2.55b	1.33b	0.88b
T_3	4.11	2.00b	1.11b	5.11b	2.22b	1.33b	0.88b
T_4	4.55	1.88b	1.00b	4.11b	1.77b	1.11b	0.77b
T_0	4.77	9.44a	12.44a	10.22a	12.44a	13.78a	12.56a
P value	0.12	0.00	0.00	0.00	0.00	0.00	0.00
F Value	2.74	57.81	36.80	15.30	27.51	41.75	84.66
LS	NS	**	**	**	**	**	**

LS = Level of significance

** and NS =Significant at 1% level and non-significant respectively

Means followed by common letter(s) are not significantly different

[Where, T_1=Imidacloprid, T_2=Cypermethrin, T_3= Chlorpyrifos, T_4= Abamectin and T_0=Control]

Effect of Synthetic Insecticides on the Number of Natural Enemies (NEs)

The data presented in Table 2 depict the number of natural enemies (NEs) over a series of treatments using four different synthetic insecticides (T_1, T_2, T_3, T_4) and an untreated control (T_0). The data spans from before treatment to after three spray applications. Before treatment, the initial count of natural enemies was varied across treatments, with T_1 starting at 2.33, T_2 at 3.00, T_3 at 2.67, T_4 at 3.67, and the control (T_0) at 3.33. After the first spray application, there was a reduction in the number of natural enemies for all treatments except for the control (T_0), which saw a significant increase. The increase in natural enemy populations in the untreated control likely resulted from favorable *kharif* conditions, which supported both CLM and their natural enemies. For example, T_1 decreased from 1.11 to 0.66, T_2 from 1.77 to 0.77, T_3 from 1.22 to 0.66, T_4 from 1.88 to 1.22, while T_0 increased to 6.44.

Imidacloprid (T_1) consistently demonstrated the highest reduction in natural enemy populations across all time points post-treatment. This supports the findings by Prabhaker et al. (2011), which reported significant negative effects on parasitoids and predators due to Imidacloprid. While all insecticides tested (T_1, T_2, T_3, T_4) reduced NE populations compared to the control, Imidacloprid had the most pronounced effect. This aligns with studies by Grafton-Cardwell et al. (2008), which noted significant suppression of natural enemies due to systemic insecticides like Imidacloprid. This also aligns with studies by Akter et al. (2024) which noted that abundance of ladybird beetles was highest in untreated control plots. Chlorpyrifos is severely toxic to the non-target organisms (Sud et al., 2020). It is well-documented that Chlorpyrifos have adverse effect on natural enemies including ladybirds (Cloyd, 2012) other hands other studies stated spinosad and soap with insecticidal property are harmless to natural enemies (Jalali et al., 2009; Jansen et al., 2010).

Table 2. Effect of four synthetic insecticides on natural enemies (Ladybird Beetle) plant^{-1}

Treatment	No. of NEs (Ladybird Beetle)						
	Before Treatment	1st Spray		2nd Spray		3rd Spray	
		1st week	2nd week	1st week	2nd week	1st week	2nd week
T_1	2.33	0.66b	3.44b	1.33b	0.55b	0.44b	1.11b
T_2	3.00	0.77b	4.55b	2.22b	1.11b	1.11b	1.77b
T_3	2.67	0.66b	4.66b	2.22b	1.11b	1.00b	1.22b
T_4	3.67	1.22b	5.11b	2.33b	1.22b	1.22b	1.88b
T_0	3.33	6.44a	9.33a	9.00a	10.55a	12.00a	10.55a
P value	0.17	0.00	0.00	0.00	0.00	0.00	0.00
F Value	2.00	32.04	17.02	56.46	73.11	25.65	86.27
LS	NS	**	**	**	**	**	**

LS = Level of significance

** and NS = Significant at 1% level and Non-significant respectively

Means followed by common letter(s) are not significantly different

[Where, T_1=Imidacloprid, T_2=Cypermethrin, T_3= Chlorpyrifos, T_4= Abamectin and T_0=Control]

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Conclusion

The study tested insecticides in controlling CLM in the field conditions. Among the tested insecticides, Imidicloprid provides the minimum leaf infestation and lowest larval count. However, all insecticide reduced the number of NEs (ladybird beetles) compared to untreated control. Therefore, it could be concluded that this study established the fact that among the four-synthetic insecticides, Imidicloprid were demonstrated to be highly operative against citrus leaf miner (CLM) under field conditions.

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