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Effectiveness of Drone-Assisted Thiamethoxam12.6% + Lambda-Cyhalothrin 9.5% ZC against Pink Bollworm (*Pectinophora gossypiella*) in Cotton

D P Padvi [a++*], N K Bhute [b#], S T Aghav [a†], N K Medhe [c†] and C B Wayal [d‡]

[a] Department of Entomology, Post Graduate Institute Mahatma Phule Krishi Vidyapeeth, Rahuri, 413-722 Maharashtra, India.
[b] Cotton Improvement Project, Mahatma Phule Krishi Vidyapeeth, Rahuri, 413-722 Maharashtra, India.
[c] Department of Agronomy, Cotton Improvement Project, Mahatma Phule Krishi Vidyapeeth, Rahuri, 413-722 Maharashtra, India.
[d] Department of Entomology, Pulse Improvement Project, Mahatma Phule Krishi Vidyapeeth, Rahuri, 413-722 Maharashtra, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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[++] M.Sc. Scholar;
[#] Assistant Entomologist;
[†] Assistant Professor;
[‡] Scientist;
**Corresponding author: Email: divyapadvi18@gmail.com;*

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ABSTRACT

The field study was carried out at, AICCIP, MPKV, Rahuri-413 722 during Kharif, 2023. An investigation was undertaken with an objective, to evaluate the effect of Thiamethoxam 12.6% + Lambda-cyhalothrin 9.5% ZC insecticides against pink bollworm through drone application. The study was conducted using a randomized block design (RBD) with multiple insecticidal treatments, including drone and knapsack sprayer applications. The results revealed that among the tested insecticidal treatments Thiamethoxam 12.6% + Lambda-cyhalothrin 9.5% ZC @44 gm a.i./ha through drone application was recorded less rosette flower (4.42%), green boll damage(3.64%) and 2.11 pink bollworm larvae per 20 bolls. At harvest, the treatment recorded less open boll damage (6.68%) and locule damage (2.96%). The treatment @44 gm a.i./ha through knapsack sprayer found at par with it which had a non-significant difference among them. The treatment Thiamethoxam 12.6% + Lambda-cyhalothrin 9.5% ZC @55 gm a.i./ha through drone application was only for evaluation of phytotoxicity. These findings highlight the effectiveness of drone-based insecticide application as a promising tool for sustainable pest management in large-scale cotton farming.

Keywords: Pink bollworm. Cotton; drone; efficacy; Thiamethoxam 12.6% + Lambda-cyhalothrin 9.5% ZC.

1. INTRODUCTION

Cotton, often referred to as "White Gold" or the "King of Natural Fibers," is a key commercial crop in the Malvaceae family. It is a significant fiber crop with global importance, grown in over seventy countries. The cotton industry plays a crucial role in the economic, social, and political dynamics of the world. It supports millions of jobs in agriculture, manufacturing, and related industries, making it a vital source of livelihood for rural communities (FAO, 2020). Cotton cultivation supports many farmers and agricultural workers in Maharashtra, boosting rural incomes and promoting economic stability in the region. Additionally, cotton from Maharashtra is vital to India's textile industry, significantly contributing to the GDP and export revenues. Cotton production generates income for 250 million people globally and employs nearly 7 percent of the workforce in developing nations (WWF-2019).

Maharashtra is among the top cotton-producing states in India, making a substantial contribution to the nation's overall cotton production. In recent years, Maharashtra has consistently been one of the top states in terms of cotton production (Agri Exchange, 2020). In 2022-23, cotton was grown over an area of 4.182 million hectares, producing 8.025 million cotton bales, each weighing 170 kilograms, with an average yield of 343 kilograms per hectare (COCPC, 2023). Research and development in agronomy, pest management, and irrigation techniques have improved cotton yields and quality in Maharashtra. Adoption of modern agricultural practices has helped mitigate risks associated with pests, diseases, and climate variability (ICAR-CICR, 2020).

Cotton plants are attacked by approximately 1326 species of insects globally (Rajendra et al. 2018). In India, around 162 species of insect pests recorded on cotton crops. Among these, the pink bollworm is particularly harmful and has caused significant yield losses globally. Yield losses from pink bollworm infestations can range from 20% to 40%, and in severe cases, total crop failure can occur. In Maharashtra, the pink bollworm has caused losses up to 50% in some regions (Kranthi et al*.,* 2017).

The management of bollworms is critical for cotton farmers. Integrated pest management (IPM) has been the primary strategy for controlling these pests. Even though farmers mostly rely on chemical insecticides, farmers are facing several problems during application of chemical insecticides such as Labour problem, insecticidal poisoning during spray, more water and time requirement, droplet size distribution, *etc.*

In response to these challenges, new technologies such as drones, artificial intelligence, and nanotechnology are being explored to enhance pest management. Drones have shown significant potential in improving pest monitoring and pesticide application. By using drones, farmers can monitor pest populations in hard-to-reach areas and apply pesticides more efficiently, targeting only the areas with infestations. This not only reduces pesticide usage but also ensures a more precise and timely intervention, improving crop protection while reducing environmental impact. Drones also enable safer pesticide application, as they allow operators to control the UAV from a distance, minimizing human exposure to chemicals (Desale et al*.,* 2019).

Given the challenges posed by bollworm infestations and the limitations of current pest control methods, drone-mediated pest management offers a revolutionary solution. By integrating drone technology into IPM, farmers can improve pest control precision, reduce pesticide use, and enhance the overall sustainability of cotton farming

2. MATERIALS AND METHODS

The field experiment was conducted at the All India Coordinated Cotton Improvement Project, Mahatma Phule Krishi Vidyapeeth, Rahuri, during the Kharif season of 2023. The site is located at 19.38°N latitude and 74.65°E longitude, with an elevation of 511 meters above mean sea level. Cotton variety Ajeet-199 was manually sown on June 25, 2023, at a spacing of 90 cm × 90 cm. The experiment followed a randomized block design (RBD) with five treatments, four replications, and a plot size of 500 m² for each treatment. The treatments included two different spray equipment types: a drone (20 L/ha) and a knapsack sprayer (500 L/ha). The total number of sprays applied was two, with an interval of 10 days between each application. The pesticide used in all treatments was Thiamethoxam 12.6% + Lambda-cyhalothrin 9.5% ZC. The doses were as follows: in treatment 1, 33 g of active ingredient (g.ai/ha) was applied with 150 g of the product per hectare, and 75 ml of the product per 10 liters was used for drone application; in treatment 2, 44 g.ai/ha, 200 g of the product per hectare, and 100 ml per 10 liters were used for drone application; in treatment 3, 55 g.ai/ha, 250 g of the product per hectare, and 125 ml per 10 liters were used for drone application. In treatment 4, the same product was used at 44 g.ai/ha and 200 g of the product per hectare, but only 4 ml per 10 liters was applied using the knapsack sprayer. Treatment 5 served as the untreated check, with no pesticide application.

Pre-treatment counts were taken before spraying to decide the initiation of treatment, with post-treatment counts recorded 10 days after each spray. The first spraying was given after pest crossed the Economic Threshold Level (ETL), and a second spray was repeated 10–15 days later. Various parameters were observed during the study: the per cent of rosette flowers due to pink bollworm infestation was recorded weekly by selecting five randomly tagged plants. The total number of flowers and rosette flowers were counted, and the percentage of rosette flowers was calculated as Per cent Rosette flowers = (Number of Rosette flowers / Total number of flowers) × 100. For assessing the pink bollworm larval population in green bolls, 20 green bolls were collected from five randomly tagged plants before and 10 days after each spray. These bolls were cut open to count the number of live pink bollworm larvae. Green boll damage was observed by plucking 20 green bolls from five randomly selected plants, with the percentage of damage calculated as Per cent Green boll damage = (Number of damaged green bolls / Total number of green bolls observed) × 100. Locule damage was assessed at the time of picking by counting the total number of locules and the damaged locules from five randomly tagged plants. The percentage of locule damage was calculated using the formula Per cent Locule damage = (Number of damaged locules / Total number of locules) × 100. Similarly, open boll damage was recorded at the time of picking, with the number of good and bad open bolls counted from five randomly selected plants. The percentage of open boll damage was calculated as Per cent Open boll damage = (Number of bad open bolls / Total number of open bolls) × 100. Finally, the yield was recorded at harvest, expressed in quintals per hectare (q/ha).

3. RESULTS AND DISCUSSION

3.1 Rosette Flower Damage Due to Pink Bollworm

The efficacy of various insecticidal treatments on rosette flower damage is presented in Table 1. Pre-treatment observations revealed no significant differences between treatments. However, all insecticidal treatments significantly reduced the percentage of rosette flowers compared to the untreated control (9.81%). The treatment Thiamethoxam 12.6% + Lambda-cyhalothrin 9.5% ZC at 44 gm a.i./ha applied via drone recorded highest efficacy, reducing rosette flower damage by 54.94% followed by treatment with knapsack sprayer (53.61%). The treatment, Thiamethoxam 12.6% + Lambda-cyhalothrin 9.5% ZC at 55 gm a.i./ha via drone application was only for evaluation of phytotoxicity which showed 57.69%. reduction in rosette flower damage. The results suggest that the application of Thiamethoxam 12.6% + Lambda-cyhalothrin

9.5% ZC, especially via drone, is highly effective in reducing rosette flower damage, likely due to the precise targeting and coverage provided by drone application.

3.2 Green Boll Damage Due to Pink Bollworm

As shown in Table 2, pre-treatment observations indicated no significant differences between treatments. After treatment, Thiamethoxam 12.6% + Lambda-cyhalothrin 9.5% ZC at 44 gm a.i./ha applied via drone demonstrated the higher reduction in green boll damage (64.76%) and it was followed by the same formulation at 44 gm a.i./ha by knapsack sprayer (63.31%). The treatment Thiamethoxam 12.6% + Lambda-cyhalothrin 9.5% ZC at 55 gm a.i./ha applied via drone was only for phytotoxicity evaluation which recorded 66.21%reduction in green boll damage over control. These results highlight the effectiveness of the drone application in controlling green boll damage, which can be attributed to the uniform coverage and targeted delivery of insecticides, ensuring better pest control.

3.3 Pink Bollworm Larvae Population

The impact of insecticidal treatments on pink bollworm larvae populations is summarized in Table 3. Pre-treatment larvae counts were comparable across treatments. Among the remaining treatments Thiamethoxam 12.6% + Lambda-cyhalothrin 9.5% ZC at 44 g.ai/ha via drone application recorded lowest 2.11 larvae/20 bolls, which was at par with Thiamethoxam 12.6% + Lambda-cyhalothrin 9.5% ZC at 44 g.ai/ha applied using the knapsack sprayer. The phytotoxicity treatment, Thiamethoxam 12.6% + Lambda-cyhalothrin 9.5% ZC at 55 gm a.i./ha via drone application recorded 1.97 larvae/20 bolls and resulted in 67.00% reduction in larval population over control. These findings suggest that drone application provides superior pest control by ensuring efficient insecticide delivery to affected boll areas.

3.4 Open Boll Damage Due to Pink Bollworm

The open boll damage data, presented in Table 4, show that the treatments, Thiamethoxam 12.6% + Lambda-cyhalothrin 9.5% ZC at 44 gm a.i./ha, through drone and knapsack sprayer applications recorded significant reduction in open boll damage 6.68% and 6.86% respectively over control. The treatment Thiamethoxam 12.6% + Lambda-cyhalothrin 9.5% ZC at 55 gm a.i./ha applied via drone was only for evaluation of phytotoxicity which reduced open boll damage by 67.75% over control and recorded 6.50% open boll damage.

3.5 Locule Damage Due to Pink Bollworm and Yield q/ha

The effects of insecticidal treatments on locule damage are presented in Table 4. The treatments Thiamethoxam 12.6% + Lambda-cyhalothrin 9.5% ZC applied at 44 gm a.i./ha via drone and knapsack sprayer showed significant reductions in locule damage (84.40% and 83.40%, respectively) over control. The phytotoxicity treatment Thiamethoxam 12.6% + Lambda-cyhalothrin 9.5% ZC at 55 gm a.i./ha via drone, reduced locule damage by 85.14%. These results suggest that the combination of these insecticides, especially when applied via drone, is highly effective in minimizing locule damage, which is essential for improving the overall health and yield of cotton crops. The treatment Thiamethoxam 12.6% + Lambda-cyhalothrin 9.5% ZC applied at 44 gm a.i./ha via drone recorded higher yield of 15.60 q/ha (Table 4) and which was followed by knapsack sprayer (15.45 q/ha). The phytotoxicity treatment Thiamethoxam 12.6% + Lambda-cyhalothrin 9.5% ZC at 55 gm a.i./ha via drone observed yield of 15.72 q/ha.

The results of this study highlight the effectiveness of Thiamethoxam 12.6% + Lambda-cyhalothrin 9.5% ZC in controlling pink bollworm infestation, with the drone-based application proving to be particularly effective in reducing boll damage. This treatmentat Thiamethoxam 12.6% + Lambda-cyhalothrin 9.5% ZC at 44 gm a.i./ha, through drone application consistently outperformed than other treatments followed by knapsack sprayer. The use of drones ensures uniform coverage, reduced drift, and improved pest control, which could be particularly valuable in large-scale cotton farming.

The findings of this study are in agreement with previous research, including the work of Xiofeng et al. (2021), who observed the efficacy of Thiamethoxam + Lambda-cyhalothrin through drone application against the lepidopteran pest Cnidocampa flavescens in walnut orchards. Similarly, Changfen et al. (2022) found that UAV spraying at different volumes and concentrations was effective in controlling fall armyworm populations. These studies support the notion that drone application is an effective pest management tool in various crops.

Table 1. Efficacy of different insecticidal treatments on rosette flower due to the pink bollworm

Tr. No.	Treatments	Method	Dose gm or ml a.i./ha	Rosette flower (%)				ROC (%)
				Precount	1st Spray	2nd Spray	Mean	
1.	Thiamethoxam 12.6% + Lambda-cyhalothrin 9.5% ZC	Drone	33	7.91 (16.25)	6.12 (14.49)	3.12 (10.23)	4.62 (12.36)	52.90
2.	Thiamethoxam 12.6% + Lambda-cyhalothrin 9.5% ZC	Drone	44	7.35 (15.73)	5.91 (14.07)	2.92 (9.84)	4.42 (11.95)	54.94
3.	Thiamethoxam 12.6% + Lambda-cyhalothrin 9.5% ZC	Drone	55	7.55 (15.95)	5.52 (13.59)	2.79 (9.61)	4.15 (11.60)	57.69
4.	Thiamethoxam 12.6% + Lambda-cyhalothrin 9.5% ZC	Knapsack	44	7.62 (16.02)	6.05 (14.21)	3.05 (10.06)	4.55 (12.14)	53.61
5.	Untreated (control)	-	-	8.10 (16.53)	9.56 (17.99)	10.05 (18.47)	9.81 (18.23)	-
SE ±				**0.40**	**0.29**	**0.20**	**0.25**	**-**
CD at 5%				**NS**	**0.89**	**0.61**	**0.75**	**-**

**(Figures in parentheses are arcsine transformed values) (ROC- Reduction Over Control)*
(NS- Non significant)

Table 2. Efficacy of different insecticidal treatments on green boll damage due to pink bollworm

Tr. No.	Treatments	Method	Dose gm or ml a.i./ha	Green boll damage (%)				ROC (%)
				Pre count	1st Spray	2nd Spray	Mean	
1.	Thiamethoxam 12.6% + Lambda-cyhalothrin 9.5% ZC	Drone	33	8.02 (16.43)	5.00 (12.92)	2.91 (9.83)	3.95 (11.38)	61.76
2.	Thiamethoxam 12.6% + Lambda-cyhalothrin 9.5% ZC	Drone	44	7.88 (16.28)	4.65 (12.45)	2.62 (9.31)	3.64 (10.88)	64.76
3.	Thiamethoxam 12.6% + Lambda-cyhalothrin 9.5% ZC	Drone	55	7.52 (15.91)	4.42 (12.13)	2.55 (9.20)	3.49 (10.67)	66.21
4.	Thiamethoxam 12.6% + Lambda-cyhalothrin 9.5% ZC	Knapsack	44	7.95 (16.37)	4.79 (12.63)	2.79 (9.61)	3.79 (11.12)	63.31
5.	Untreated (control)	-	-	8.15 (16.58)	9.76 (18.18)	10.89 (19.25)	10.33 (18.72)	-
SE ±				**0.36**	**0.25**	**0.20**	**0.23**	**-**
CD at 5%				**NS**	**0.78**	**0.62**	**0.70**	**-**

**(Figures in parentheses are arcsine transformed values) (ROC- Reduction Over Control)*
(NS- Non significant)

Table 3. Efficacy of different insecticidal treatments on the larval population of pink bollworm

Tr. No.	Treatments	Method	Dose gm or ml a.i./ha	Pink Bollworm Larvae/20 bolls				ROC (%)
				Precount	1st Spray	2nd Spray	Mean	
1.	Thiamethoxam 12.6% + Lambda-cyhalothrin 9.5% ZC	Drone	33	4.33 (2.20)	2.75 (1.82)	1.80 (1.51)	2.27 (1.67)	61.97
2.	Thiamethoxam 12.6% + Lambda-cyhalothrin 9.5% ZC	Drone	44	4.56 (2.25)	2.58 (1.75)	1.63 (1.46)	2.11 (1.61)	64.65
3.	Thiamethoxam 12.6% + Lambda-cyhalothrin 9.5% ZC	Drone	55	4.15 (2.16)	2.41 (1.71)	1.54 (1.43)	1.97 (1.57)	67.00
4.	Thiamethoxam 12.6% + Lambda-cyhalothrin 9.5% ZC	Knapsack	44	4.21 (2.17)	2.62 (1.77)	1.72 (1.49)	2.17 (1.63)	63.65
5.	Untreated (control)	-	-	4.68 (2.27)	5.90 (2.53)	6.05 (2.56)	5.97 (2.54)	-
SE ±				**0.04**	**0.03**	**0.02**	**0.03**	**-**
CD at 5%				**NS**	**0.10**	**0.07**	**0.09**	**-**

**(Figures in the parentheses are $\sqrt{x+0.5}$ transformed values) (ROC- Reduction Over Control)*
(NS: Non-Significant)

Table 4. Efficacy of different insecticidal treatments on open boll damage and locule damage due to pink bollworm

Tr. No.	Treatments	Method	Dose gm or ml a.i./ha	Open boll damage (%)	ROC (%)	Locule damage (%)	ROC (%)	Yield (q/ha)
1.	Thiamethoxam 12.6% + Lambda-cyhalothrin 9.5% ZC	Drone	33	7.02 (15.72)	65.17	3.21 (10.29)	83.08	14.68
2.	Thiamethoxam 12.6% + Lambda-cyhalothrin 9.5% ZC	Drone	44	6.68 (14.98)	66.86	2.96 (9.91)	84.40	15.60
3.	Thiamethoxam 12.6% + Lambda-cyhalothrin 9.5% ZC	Drone	55	6.50 (14.77)	67.75	2.82 (9.67)	85.14	15.72
4.	Thiamethoxam 12.6% + Lambda-cyhalothrin 9.5% ZC	Knapsack	44	6.85 (15.16)	66.02	3.15 (10.22)	83.40	15.45
5.	Untreated (control)	-	-	20.16 (26.67)	-	18.98 (25.82)	-	8.34
SE ±				**0.30**	**-**	**0.20**	**-**	**0.09**
CD at 5%				**0.94**	**-**	**0.61**	**-**	**0.28**

**(Figures in parentheses are arcsine transformed values) (ROC- Reduction Over Control)*
(NS- Non significant)

Furthermore, the results align with Joker (2021), who reported the superiority of UAV spraying over traditional sprayers for pest control, emphasizing the benefits of uniform coverage and targeted pesticide delivery provided by drones. The present study also corroborates the findings of Swami et al. (2019), who found that the combination of Thiamethoxam 12.6% + Lambda-cyhalothrin 9.5% ZC was effective in controlling lepidopteran pests in black gram, further highlighting the versatility and effectiveness of this insecticide combination.

This study shows the conformity with study conducted by Nandwalkar et al. (2024) who reported the effectiveness of thiamethoxam 12.6% + Lambda cyhalothrin 9.5% ZC against pink bollworm (*Pectinophora gossypiella* Saunders) in Bt cotton through drone application.

Overall, the significant reductions in rosette flowers, green boll damage, larvae populations, open boll damage, and locule damage in this study indicate that the Thiamethoxam 12.6% + Lambda-cyhalothrin 9.5% ZC combination, especially when applied via drone, is highly effective in managing pink bollworm and improving cotton crop health and yield.

4. CONCLUSION

The study demonstrates that drone-based application of Thiamethoxam 12.6% + Lambda-cyhalothrin 9.5% ZC at 44 gm a.i./ha effectively controls pink bollworm infestation in cotton, significantly reducing boll damage and improving crop yield. The drone application method proved better than traditional knapsack spraying, ensuring uniform pesticide distribution, minimizing drift, minimizes time, labour and requires less water. The results align with previous studies, reinforcing the potential of drone technology in pest management for cotton and other crops.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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